DOCUMENT RESUME

ED 038 503 VT 010 326

TITLE	Heavy Construction Equipment Mechanic; A Suggested Guide for a Training Course.
INSTITUTION	Office of Education (DHEW), Washington, D.C. Div. of Manpower Development and Training.
REPORT NO	OE-87044
PUB DATE	69
NOTE	50p.
AVAILABLE FROM	Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (FS5.287:87044, $.50)
EDRS PRICE	EDRS Price MF-$0.25 HC-$2.60
DESCRIPTORS	Curriculum Guides, *Equipment Maintenance, *Machine Repairmen, Mechanics (Process), *Program Guides, Skilled Occupations, *Teaching Guides, *Trade and Industrial Education
IDENTIFIERS	*Heavy Construction Equipment Mechanic

ABSTRACT

Prepared by a technical writer for the Division of Manpower Development and Training, this guide is intended to aid instructors, supervisors, and administrators of vocational education and manpower training programs in establishing training programs for mechanics and technicians entering the occupation of servicing heavy construction equipment. The content provides suggested course outlines, teacher qualifications, student prerequisites, time allocation, instructional material, teaching suggestions, and methodology, as well as information regarding employment opportunities and career progression. The 26 course units outlined include: (1) Hand and Power Tool Orientation, (2) Engines and Engine Systems, (3) Principles of Hydraulics, (4) Automatic Transmissions, (5) Batteries and Fundamentals of Electricity, (6) Welding Fundamentals, (7) Air Conditioning, (8) Industrial Air Compressors, (9) Industrial and Labor Relations, and (10) Shop Economics and Work Relationships. A bibliography, references, films, glossary of terms, suggested shop layout, and suggested list of equipment, tools, and training aids also are given. (AW)

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heavy construction equipment mechanic

a suggested guide for a training course

VT 010 326

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ED038503

OE-87044

HEAVY CONSTRUCTION EQUIPMENT MECHANIC

(D.O.T. Occupational Code 620.281)

A Suggested Guide for a Training Course

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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OFFICE OF EDUCATION

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Manpower Development and Training Program

VT 010 326

Superintendent of Documents Catalog No. FS 5.287:87044

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1969

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 50 cents

Foreword

This guide has been developed to be of assistance to instructors, supervisors, and administrators of vocational education and manpower training programs. It offers suggested course outlines, shop layouts, and lists of equipment, tools, training aids, and their cost. The contents of this guide may be changed and adapted to meet the local needs of any vocational or manpower training program.

This guide is, in part, the summation of contributions from:

George O. Anderson, Nebraska Vocational and Technical Institute
Earl M. Bowler, U.S. Office of Education
J. W. Duncan, International Harvester Company
Robert H. Engstrom, Darr Equipment Company
Michael J. Matanich, Staples Area Vocational-Technical School
E. M. McKevitt, John Deere and Company
Julian J. Smith, Caterpillar Tractor Company
Lee White, Darr Equipment Company

This guide was developed under the direction of F. J. Konecny, Assistant Director of James Connally Technical Institute, for the Division of Manpower Development and Training. The course material was prepared by Charles E. McCoy, technical writer for the above-mentioned school.

Recognition and appreciation is also extended to the many participating manufacturers, associations, equipment dealers, vocational and technical schools, and a military service school for the assistance they provided.

HOWARD A. MATTHEWS
Director, Division of Manpower Development and Training

GRANT VENN
Associate Commissioner for Adult, Vocational, and Library Programs

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Purpose

The purpose of this guide is to augment information available through the Office of Education of the U.S. Department of Health, Education, and Welfare for schools or institutions and manpower training centers and to aid in the establishment of a training program for mechanics and technicians entering the occupation of servicing heavy construction equipment. Existing schools and manpower projects can profit from this guide because it will provide information for reviewing and updating their programs.

The guide is designed to assist school administrators, supervisors, and teachers who will be planning and developing new programs or evaluating existing programs in training heavy construction equipment mechanics. Although the indicated level of instruction is post high school, the instruction can be adapted to start at any level.

This guide establishes suggested boundaries for teacher qualifications, student prerequisites, time allocation, instructional material, and methodology. Information gathered regarding employment opportunities and career progression is also included.

This program is designed to train school students and manpower project trainees to enter the labor market with technical knowledge of pertinent equipment and general information in subjects relevant to the occupation. The training program encompasses applied mathematics, physics, and other courses directly related and designed to increase the student's ability to succeed in this ever-increasing complex occupation. A student completing this program will advance much faster than one learning on the job without prior training. As the equipment becomes more versatile and automatic, more skill is required to service it.

Another training guide, more specialized in the industrial engine area, is available and will supplement this guide as an aid to administrators, supervisors, and teachers. It is prepared in more detail to develop skills in engine overhaul.

Occupational Information

The following job description is quoted from *The Dictionary of Occupational Titles:*

> Engineering—Equipment Mechanic
>
> 620.281. Heavy equipment mechanic. Analyzes malfunctions and rebuilds, repairs, and adjusts heavy construction equipment other than internal combustion engines, such as cranes, power shovels, scrapers, paving machines, conveyors, and bulldozers; dismantles machine, using hoists, hand and power wrenches, screwdrivers, and pliers. Inspects parts for damage or excessive wear. Verifies that clearance and dimensions of parts, such as shafts, bearings, bushings, pins, gears, and rollers meet factory specifications, using gauges, such as calipers and micrometers. Directs assistant engaged in disassembly and assembly of machines and cleaning of parts. May specialize in making field repairs to equipment sufficient to resume operation but not involving major overhaul or rebuilding and be designated as Field Mechanic.

Employment Opportunities

The heavy construction equipment industry is an excellent field for youths interested in a career in mechanics. The demand for mechanics in this area far exceeds the supply. Production of heavy construction equipment has increased an average of 20 percent annually for the past 6 years and estimates for years to come are even greater.

One manufacturer, producing 20 percent of the machines manufactured of one type, did research to determine how serious the mechanic shortage in their field service is.* He found that there was an immediate demand for 2,334 mechanics in their dealerships if they were available. Based on his figures, there would be an estimated demand for 11,670 mechanics immediately in the dealership area. In addition to this, the need for mechanics in contractors' shops makes it easy to realize that there is a critical shortage of mechanics to service heavy construction equipment.

The advanced technology of modern machines requires mechanics with knowledge directly related to the industry of heavy construction, such as blueprint reading, working from schematics to troubleshoot, and the ability to use service manuals and parts references. Automatic controls and drives being installed on modern equipment have expanded the use of electricity, air, and hydraulics until mechanics have to be capable of more than simple mechanical functions. A graduate from a heavy construction equipment school or manpower training course would have an advantage over untrained applicants getting started in the mechanical field, and an added advantage of having had such adequate training is that his knowledge will increase his advancement opportunities as experience develops his skill.

Salaries of mechanics in heavy equipment services are above that of average mechanics working in general repair shops throughout the country. Outstanding mechanics in heavy construction equipment shops enjoy better opportunities for advancement to better positions within the industry.

A survey of many successful corporations was made to determine what they think a student's qualifications should be for entering a training program. These four qualifications were considered essential:

Age: 18 years old by graduation date. Mature, with a capability of making intelligent decisions because of the safety and economy factors essential to construction equipment service shops.

Education: High school or equivalent; capable of learning technical subjects made necessary by the automatic and remote control systems used on modern construction equipment.

Physical Condition: Students should have normal or corrected vision. They should have no physical handicaps that would impair coordination or prevent their doing strenuous work for extended periods under adverse conditions, as is sometimes required. The student should be capable of lifting heavy parts, and using mechanics' tools and equipment.

Personal Attributes: Students should be alert, courteous, cooperative, and dependable as evidenced by school records or previous employment. The student should show aptitude (determined by tests) for working successfully as a mechanic.

*Survey conducted by Fred Hileman of John Deere & Company.

Organizing and Teaching the Course

Teacher Qualifications

Teachers of vocational-technical programs shall have a minimum of 3 years successful occupational experience beyond apprenticeship, post high school, plus 60 clock hours of teacher training before employment, and have graduated from appropriate trade schools or, if military, from appropriate service schools.

The teacher should have a pleasant personality and should be in good health. He should be adept at presenting technical matter and demonstrating operations the students will be expected to perform in the occupation.

Teaching Procedures

Organized lectures are necessary for introducing most subjects, but the emphasis should be on shop experience with as much student participation as possible.

The resourceful teacher can use this guide to provide students with the maximum learning possible in preparing them to enter the occupation of heavy construction equipment mechanic, which includes working with many different pieces of equipment.

The suggested times for instruction will vary with the collective background of the students. The instructional topics in each unit are suggested to be taught in blocks, with specific suggestions included with each unit along with suggested student assignments for that phase of instruction.

Lesson planning is the responsibility of the instructor, with the guide furnishing a suggested sequence for presenting the subject items included. A teacher in each area of training should evaluate the students' progress to determine if they have advanced sufficiently to permit the introduction of new material. Included in the manual is a sample test which might be used as a pattern for testing the students. The teacher should also devise practical means of evaluating students' progress as they perform assignments.

Training Facility

Suggestions are included to assist in establishing a program along with a list of tools, equipment, and supplies essential to a heavy construction equipment mechanic training facility.

A qualified teacher should be able to set up a complete program and teach the course effectively with these units as a guide.

Unit	*Title*	*Classroom Hours*	*Shop Hours*
I.	Orientation	3	3
II.	Hand and Power Tool Orientation	3	9
III.	Shop Equipment and Mechanical Measuring Devices	3	3
IV.	Engines and Engine Systems	50	110
V.	Friction Clutches and Torque Conversion	35	25
VI.	Principles of Mechanical Linkage, Levers, and Gears	18	12
VII.	Sliding Gear Transmissions	30	46
VIII.	Differential and Final Drives (Mechanical)	40	50
IX.	Principles of Hydraulics	20	10
X.	Hydraulic Systems	30	30
XI.	Fluid Couplings and Torque Convertors	20	40
XII.	Automatic Transmissions	30	60
XIII.	Brake and Booster Systems	30	60
XIV.	Accessory Case Engine Driven Air Compressors	10	20
XV.	Machinery Deck-Booms and Attachments	20	40
XVI.	Fundamentals of Piston Pumps and Pump Systems	20	40
XVII.	Batteries and Fundamentals of Electricity	18	6
XVIII.	Fundamentals of Electric Starting Motors and Generators	15	45
XIX.	Electrical Regulators and Controls	15	45
XX.	Welding Fundamentals	15	45
XXI.	Undercarriage and Wheeled Vehicles	30	60
XXII.	Lubrication	10	20
XXIII.	Air Conditioning	20	45
XXIV.	Industrial Air Compressors	20	15
XXV.	Industrial and Labor Relations	3	0
XXVI.	Shop Economics and Public Relations	3	0
	Subtotals	511	839
			511
	Total		1,350

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Course Units

Unit I

ORIENTATION

Training Time

Classroom, 3 hours; shop, 3 hours

Objectives

To introduce students to the heavy construction equipment mechanic occupation, type of working conditions that might be expected, and the rewards of successful training.

To develop working procedures for preventing injury to self or others, as well as preventing damage to machines and equipment.

To explain shop rules governing student behavior, and reporting procedures for hazardous conditions detected, or accidents, if any.

To establish policies and procedures for students in the class and shop.

Unit Outline

A. Introduction to occupation
   1. Guest speaker to outline, "A Career in the Heavy Equipment Industry"
   2. Industry background film, "Use of Machines in Our Industrial Life"
B. Personal safety
   1. Student responsibility in individual and group activities
   2. Student behavior and safe attitudes
   3. Handling heavy or bulky items
      a. Manual lifting techniques
      b. Lifting techniques with hoisting devices
      c. Hand signals for hoisting or moving equipment
   4. Protective measures
      a. Appropriate attire
      b. Protective devices, such as safety glasses
      c. Qualifications to operate machines and equipment
C. Shop precautions
   1. General operating procedure for each piece of equipment
   2. General procedures for assigned jobs
      a. Preferred shop procedures
      b. Safety precautions to be observed
      c. Use of hoists, welding equipment, and grinders in a manner safe for self and others
   3. Fire precautions
      a. Housekeeping
      b. Oil rag containers
      c. Fuel and oil storage
         (1) Color code
         (2) Marking
      d. Fuel and oil handling for jobs
   4. Firefighting equipment
      a. Location
      b. Operation
D. Accident prevention
   1. Reporting hazards and accidents
   2. Safety inspections
E. Occupational practices in training
   1. Classroom policies—assignments, tests, notebooks, guest speakers, and field trips
   2. Shop procedures
      a. Equipment—use and care
      b. Job assignments

Teaching Suggestions

Invite a guest speaker who has attained success in the heavy construction equipment industry to greet the students, and show a film on the manufacture or servicing of the equipment.

Show safety film to illustrate how hazards can disable for life and how accidents happen. Practice or conduct drills to make certain the students are developing good safety habits.

Demonstrate how to use stands under vehicles when working under them and have the students practice putting a vehicle on stands.

Show a film or demonstrate the proper use of the firefighting equipment installed in the shop and of the types of fires that are related to heavy construction equipment repair shops.

Student Assignments

Give the students a written and practical examination, requiring they pass it with a satisfactory mark; file results in their records. Make the test complete and comprehensive to show proof of nonnegligence that might result in legal action from an accident.

References

Kates. *Diesel and High Compression Gas Engines.*
Williams. *Accident Prevention Manual for Shop Teachers.*

Films

Basic Shop Safety. Jam Handy Organization.
Roll of Drums. Caterpillar Dealer.
Senior Safety Series. McGraw-Hill.
Use of Machines in Our Industrial Life Series. McGraw-Hill.

Unit II

HAND AND POWER TOOL ORIENTATION

Training Time

Classroom, 3 hours; shop, 9 hours

Objectives

To teach the student tool nomenclature and how to select, use, and maintain such tools.

To acquaint students with power tools common to heavy construction equipment service shops, and develop the students' ability to use them safely and properly.

Unit Outline

A. Safety factors
    1. Mushroom heads on chisels, punches, and other impact tools
    2. Screwdriver hazards
    3. Tools in poor condition
        a. Hammer handles loose
        b. Defective tools
    4. Eye protection
B. Application and maintenance of tools
    1. Wrenches
        a. Ratchets, sockets, and extensions
        b. Torque and torque multipliers
        c. Adjustable
        d. Box
        e. Open-end
        f. Spanner
    2. Pullers
        a. Hand
        b. Power
    3. Taps, dies, reamers, and extractors
    4. Tube cutting and flaring sets
    5. Pliers and lock-ring tools
    6. Screwdrivers, chisels, and punches
        a. Grinding mushroom heads
        b. Grinding working edges
    7. Hammers, all types
    8. Hacksaw frames and blades
C. Power tools
    1. Safety precautions for operating
    2. Electrical grounds
    3. Power drill
        a. Drilling operations
        b. Reaming operations
        c. Honing operations
    4. Portable sanders, grinders, and buffers
    5. Pedestal and bench grinders
    6. Impact and vibrator tools
    7. Clamping or securing jobs for power tool operations

Teaching Suggestions

Display and name each tool and explain uses for each. Discuss quality, maintenance, and storage each time a new tool is introduced.

Demonstrate proper application of hand tools and explain how torque should be applied, for instance, in using the adjustable open-end wrench.

Explain systematic procedure for inspecting power tools. Have students participate in oral discussions of all power tools and stress the importance of such points as air hose fittings and the danger of a loose air hose, or an electrical arc in an ungrounded tool.

Demonstrate grinding mushroom head from a chisel or punch, and how to grind working edges of chisels, drills, and punches.

Student Assignments

Place a variety of tools on a work bench and have each student identify the tool, including its size, where appropriate.

Have each student practice with a hammer and chisel by splitting a nut off a bolt in a prepared mock-up.

Have each student check an electric drill, clamp a ½″ x 1½″ round stock in a vise, center punch one end, and drill a hole through it lengthwise to see how near the center of the stock he can come out the opposite end.

References

Crouse. *Automotive Mechanics*, chapter 2, pp. 1–21.
General Motors. *ABC of Tools.*
Snap-On-Tools Corporation. *How's Your 'Safety Rating'.*

Unit III

SHOP EQUIPMENT AND MECHANICAL MEASURING DEVICES

Training Time

Classroom, 3 hours; shop, 3 hours

Objectives

To develop the student's ability to use repair equipment common to heavy construction equipment shops safely and effectively, without endangering himself or the equipment.

To develop an understanding of the application of measuring devices used to service or repair construction equipment.

Unit Outline

A. Safety factors—guest speaker: "Typical Accidents Causing Time Loss"
B. Shop equipment applications
    1. Jack nomenclature
        a. Mechanical
        b. Hydraulic
        c. Air, and air-over hydraulic
    2. Practical application of jacks
        a. For placing equipment on stands
        b. For positioning and aligning components
    3. Hoist nomenclature
        a. Overhead installations, fixed and rail
        b. Floor, installed and mobile
    4. Press nomenclature
        a. Hydraulic
        b. Mechanical
    5. Press applications
        a. Positioning for assorted job sizes
        b. Clamps and jigs for assorted job types
    6. Parts cleaning equipment
        a. Solvent units
        b. Steam systems
C. Mechanical measuring devices
    1. Scales or common rule
        a. Decimals and fractions
        b. Machinist's square and protractor
    2. Calipers
        a. Inside and outside
        b. Transferring readings with calipers
    3. How to use and read micrometers
        a. Outside micrometer
        b. Inside micrometer
        c. Depth micrometer
    4. Use of gauges
        a. Feeler gauge
        b. Thread gauge
        c. Radius gauge
    5. How to use the dial indicator

Teaching Suggestions

Invite a guest speaker professionally employed in accident prevention.

Demonstrate to the class, in the shop, the proper method for using each piece of equipment. Promote class participation as demonstrations progress.

Use the various measuring devices on actual equipment to demonstrate their purposes. Then introduce the principles of each measuring device, how to read each accurately, and how to care for each.

Student Assignments

Have student team practice putting a vehicle on stands, as though they would work under it; then have them lower it back to the floor.

Have a team demonstrate use of a hoist and practice hand signal drill.

Have a team demonstrate use of a press.

References

Caterpillar Dealer. *Proper Use of Jacks, Cranes, Presses, Pullers and Chains.*
Crouse. *Automotive Mechanics*, chapter 1, pp. 22–26.
Nichols. *Heavy Equipment Repair*, chapter 11, pp. 289–317.
Williams. *Accident Prevention Manual for Shop Teachers.*

Unit IV

ENGINES AND ENGINE SYSTEMS

Training Time

Classroom, 50 hours; shop, 110 hours

Objectives

To develop the student's understanding of the principles of two- and four-cycle engine operation. To

acquaint him with the nomenclature of each type, and applications for each design.

To develop an understanding of those systems necessary to make the engine perform as designed, such as: cooling, fuel, ignition, and how to troubleshoot and correct malfunctions.

Unit Outline

A. Safety factors
   1. Precautions to keep self or clothing clear of a running engine
   2. Hazards of accidentally grounding electrical circuits by tools or jewelry

B. Four-cycle gasoline engines
   1. Operating principles of the four-stroke cycle
   2. Engine nomenclature
      a. Stationary parts
      b. Moving parts

C. Two-cycle gasoline engines
   1. Operating principles of the two-stroke firing cycle
   2. Engine nomenclature
      a. Stationary parts
      b. Moving parts

D. Two- and four-cycle diesel engines
   1. Similarity of gasoline and diesel engines
   2. Operating principles of four-cycle diesel engines
      a. Natural scavenging
      b. Mechanical scavenging and supercharging
   3. Operating principles of two-cycle diesel engines
      a. Two-cycle engine blowers and superchargers
      b. Comparison of two- and four-cycle engines

E. Engine systems
   1. Ignition
      a. Principles of battery ignition circuits
      b. Distributor nomenclature; fundamentals and timing
      c. Fundamentals of spark plugs, ignition wiring, and ignition switches
         (1) Heat ranges and construction
         (2) Two- and four-cycle engine plugs
      d. Definition of a magneto
      e. Principles of creating the spark
      f. Magneto nomenclature and timing
      g. Magneto servicing and troubleshooting
   2. Carburetion
      a. Principles of one-, two-, and four-barrel carburetion
      b. Identification and operation of carburetor circuits
      c. Service adjustments and specifications
   3. Diesel fuel injection systems
      a. Fuel injection pumps; nomenclature and operating principles
      b. Fuel filters
      c. Injection nozzles
      d. Unit-type injectors
      e. Governor operating principles and fuel injector timing
      f. Servicing and troubleshooting procedures
   4. Turbochargers and blowers
      a. Nomenclature and operating principles of turbochargers
      b. Nomenclature and operating principles of blowers
      c. Synchronization and lubrication principles
      d. Failure analysis and testing procedures
   5. Liquid engine cooling
      a. Fundamentals of cooling systems
         (1) Conduction
         (2) Convection
         (3) Radiation
         (4) Temperature–pressure relationship
      b. Components of cooling systems
      c. Coolants and precautions to protect water jackets, radiators, and pumps
      d. Principles of air cooling
      e. Heat dissipating fins, shrouds, and baffles
      f. Service procedures and troubleshooting

Teaching Suggestions

Explain the precautionary procedures when working on engines that are running, such as how an automatic transmission might accidentally get into drive positions, tools, wiping rags, or clothing caught in moving parts. Also caution students to keep fingers clear of moving belts.

Prepare a checklist for types of equipment, and train each student to use it prior to starting work; to precheck, prior to cranking any engine; and to put a piece of equipment in motion.

When teaching principles of engine systems, use the components of actual equipment in your shop, augmented by material from the manufacturers.

Student Assignments

Test each student as he completes a checklist for cranking and moving a piece of equipment and for working on the engine.

Have student team take compression readings on a gasoline and a diesel engine, respectively, and explain what can be determined from these readings.

Remove the ignition wires from an engine and have each student team properly reinstall them.

Have student team remove, reinstall, and test a carburetor of a functioning engine.

References

Caterpillar Dealer. *Cooling System—Temperature and Pressure.*

Caterpillar Dealer. *Pneumatic Pressure Ratio Control.*

Crouse. *Automotive Mechanics*, chapters 5 and 6, pp. 84–146.

Nichols. *Heavy Equipment Repair*, chapter 4, pp. 93–104 and 109–135.

Unit V

FRICTION CLUTCHES AND TORQUE CONVERSION

Training Time

Classroom, 35 hours; shop, 25 hours

Objectives

To develop the student's understanding of clutch principles and their application to heavy construction equipment.

To develop the student's skill with the various clutch types, their components, and power transmission or interruption, from a constant rotating input.

Unit Outline

A. Observe safety factors
   1. When rotating the flywheel, in removal, or in replacement of pressure plate bolts
   2. When removing or replacing clutch assembly to prevent damage to self or to the equipment

B. Principles of torque conversion
   1. Mechanical principles
   2. Fluid principles

C. Friction clutches
   1. Definition and requirements of a clutch
   2. Principle parts of a clutch
      a. The driving members
      b. The driven members
      c. The operating members
   3. Types of clutches
      a. Dry single-plate clutch
      b. Dry multiple-disc clutch
      c. Wet- and dry-band clutches, and planetary applications
      d. Wet single-plate and multiple-disc clutches
      e. Dog or finger clutches

Teaching Suggestions

Emphasize the importance of making sure an engine cannot start when moving the flywheel and turning the engine.

Use mockups or cutaway models to illustrate the principles of the various types of clutches mentioned in this unit.

Demonstrate disassembly and reassembly of clutches with actual assemblies of equipment, emphasizing precautions to practice as each step is demonstrated, and adjustment.

Student Assignments

Observe each student team as it disassembles and reassembles a clutch pack for a practical evaluation score.

References

Crouse. *Automotive Mechanics*, chapter 19, pp. 426–442.

Nichols. *Heavy Equipment Repair*, chapter 6, pp. 175–198.

Unit VI

PRINCIPLES OF MECHANICAL LINKAGE, LEVERS, AND GEARS

Training Time

Classroom, 18 hours; shop, 12 hours

Objectives

To develop student understanding of the principles of mechanical linkage, leverage, and gears, as used

throughout heavy construction equipment—from the smallest components to the most powerful booms.

Unit Outline

A. Safety factors
   1. Precautions to take for personal safety
      a. Procedures to protect hands and fingers
      b. Removal of rings, watches, etc.
   2. Precautions to protect equipment
      a. Clean working habits
      b. Filters and strainers

B. Levers and gears
   1. Energy, work, and mechanical advantage
   2. Rocker arms and bell cranks
   3. Gear ratio for power and for speed
   4. Related math for lever and gear applications (see figures 1 and 2)

C. Mechanical linkage
   1. Relationship of cams and eccentrics to pushrods and rocker arms, as exemplified in an overhead valve system
   2. Pedal to link, to crossover bar, to lever principles, as utilized in a clutch assembly
   3. Principle of gearshift shaft, to lever, to linkage, to lever; back to shaft
   4. Principles of linkage and levers to control other components, such as:
      a. Boom arrangements
      b. Steering systems
      c. Fuel controls to diesel and gasoline engines
      d. Positioning control valves in power shift transmissions, and other hydraulic systems
   5. Gear failure analysis

Teaching Suggestions

Stress the tremendous forces exerted by using gears and levers, and how these forces can exceed the limits of the equipment, thus causing failures. Point out the personal dangers, as well as costly damage to the equipment, that could occur.

Teach students the various applications of gears, levers, and linkages for practical utilization, so that they will more readily comprehend the purpose for these devices in more complex components throughout the machines. Develop mockups or use cutaway models.

Measure the leverage of gear ratio and teach, from basic math, functions of simple applications, and then advance to the complexities of compound applications.

Demonstrate wear patterns of gears when misalined, or mismatched, or foreign matter is present.

There are illustrations with this unit designed to help the instructor devise training aids. They can be used as guides to develop models for the demonstration of ideas and principles; or transparencies can be made from them to be used in the classroom with an overhead projector.

Student Assignments

Have students work in teams of two. With the fulcrum at position A, have them calculate what Scale D will show when a 50-pound force is applied to Scale E. Repeat the same exercise for fulcrum positions B and C. It will be necessary to weigh the bar and determine its weight per foot.

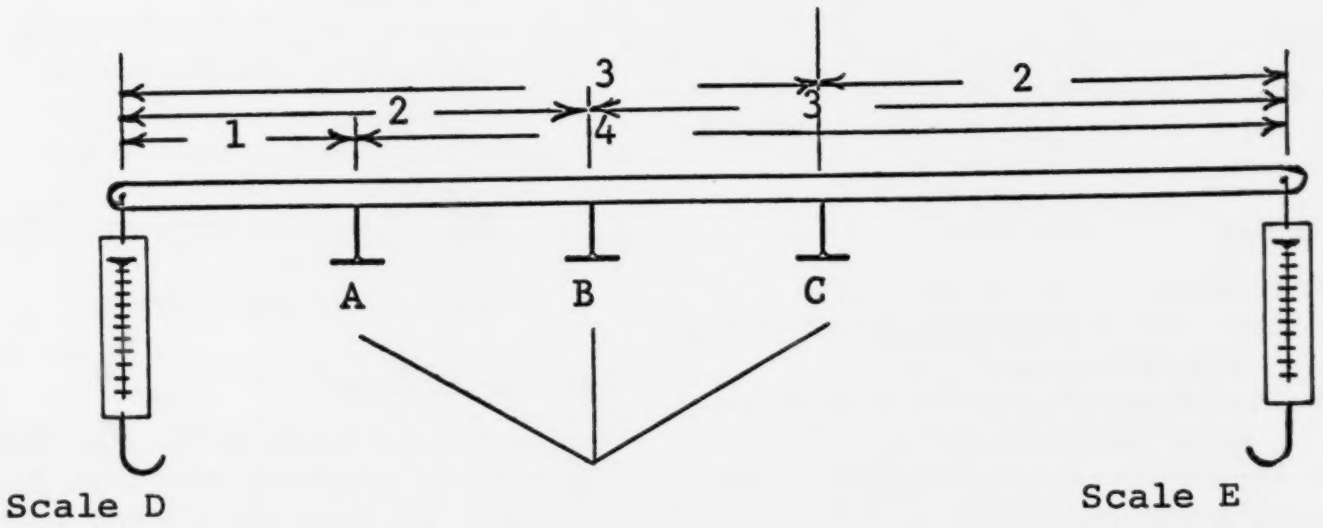

Figure 1. Fulcrum.

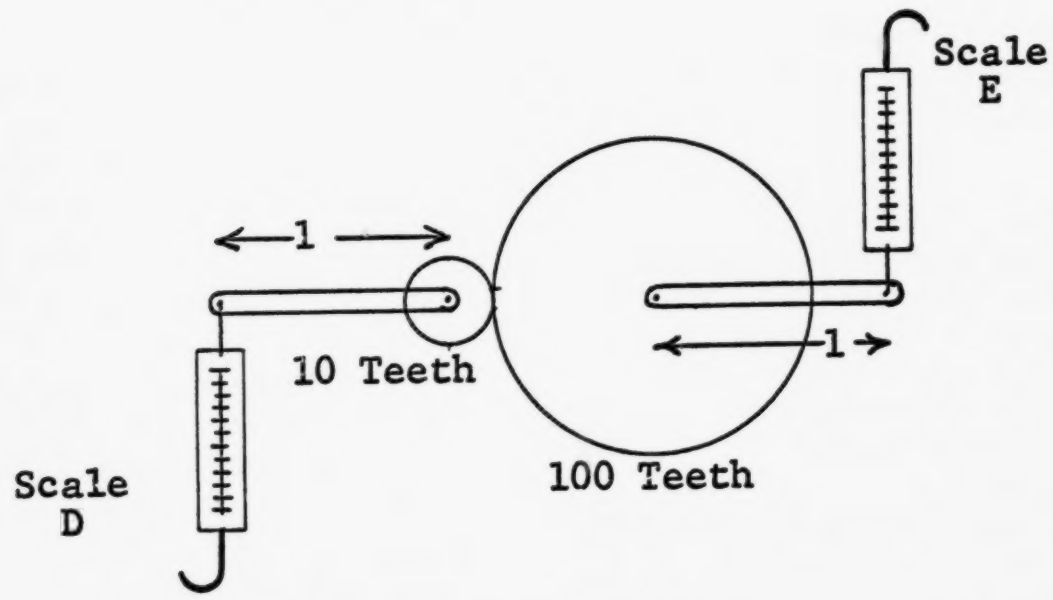

Figure 2. Leverage through gears.

Have students work in teams of two. Have the students calculate what Scale E will read when a force of 20 pounds is applied to Scale D.

Reference

Nichols. *Heavy Equipment Repair*, chapter 1, pp. 1–22.

Films

Work of Gears, Society for Visual Education.
Work of the Lever, Society for Visual Education.
Work of the Pulley, Society for Visual Education.

Unit VII

SLIDING GEAR TRANSMISSIONS

Training Time

Classroom, 30 hours; shop, 46 hours

Objectives

To develop the student's ability to diagnose and repair geared transmissions of heavy construction equipment.

Unit Outline

A. Safety factors
    1. Show film demonstrating proper manual lifting techniques
    2. Demonstrate safe procedure to position and service heavy transmissions
    3. Demonstrate safe use of transmission jacks
B. Types of geared transmissions
    1. Define transmission
    2. Single speed or gear reduction type
    3. Two or more speed gear reduction type
    4. Auxiliary transmissions
C. Geared transmission nomenclature
    1. Input shaft (known as clutch, pilot, or jack shaft)
    2. Transmission assembly
    3. Countershaft and countershaft assembly
    4. Pinion or main shaft and shaft assembly
    5. Reverse idler shaft and gear
    6. Synchromesh types
    7. Fixed clutch jaw and sliding splines
    8. Shifting forks and speed range selectors
    9. Free gears
    10. Transmission lubrication system
    11. Bearings, retainers, and shims
D. Principles of gear transmission operation
    1. Power flow for low forward speed
    2. Power flow for intermediate forward speed or speeds
    3. Power flow for high forward speeds
    4. Power flow for shifting to reverse
E. Gear transmission servicing techniques
    1. Removal and replacement of unit
    2. Disassembly procedures
    3. Inspection and servicing components
    4. Assembly procedures
    5. Gasket and oil seal techniques

Teaching Suggestions

Demonstrate and explain to the class the proper procedure to disassemble, strip, clean, and check the parts, and reassemble a geared transmission from a piece of heavy construction equipment.

Point out safety precautions to be practiced by the student as the job progresses.

After the transmission is assembled, break it down into assemblies on workbenches in the shop and explain again all the functions of the components.

Student Assignments

Have the students work in teams under immediate supervision. Have them troubleshoot, disassemble, and assemble the components of a transmission until they become proficient.

Then have them assemble the entire transmission and break it back down into components for the next team of students to perform the same operation until all students have satisfactorily mastered the assignment.

References

Crouse. *Automotive Mechanics*, chapter 23, pp. 201–212.
Nichols. *Heavy Equipment Repair*, chapter 7, pp. 478–484.

Unit VIII

DIFFERENTIAL AND FINAL DRIVES (MECHANICAL)

Training Time

Classroom, 40 hours; shop, 50 hours

Objectives

To develop the student's comprehension of the differential and final drive principles of operation, and to acquaint him with the techniques of adjusting and servicing these devices.

To develop the student's skill in disassembly, failure analysis, repair, and reassembly of mechanical final drive systems in heavy equipment.

Unit Outline

A. Safety factors
    1. Precautions for personal safety while repairing equipment
    2. Precautions to prevent damage to equipment during repair
B. Differential principles
    1. Description of simple differential
    2. Principles of operation
        a. Both drive wheels rotating
        b. One drive wheel rotating
    3. Differential locks
        a. No-spin
        b. Limited slip
        c. Torque proportioning
    4. Worm and gear drives
    5. Lubrication
C. Differential service and repair
    1. Steps to disassemble the differential
    2. Inspection of components to determine cause of failure
        a. Misalinement
        b. Foreign matter
    3. Steps to reassemble the differential
    4. Carrier bearings
    5. Adjustments, lockplates, and safety wire
D. Final drive principles
    1. Principles of wheeled vehicle final drives
        a. Direct drives
        b. Planetary drives
        c. Control principles
    2. Principles of crawler-type final drives
        a. Direct drives
        b. Planetary drives
        c. Sprocket drives
        d. Steering clutches and brakes
        e. Chain drives
        f. Control principles
E. Final drive service and repair
    1. Steps for servicing components
        a. Minor adjustments and repair not requiring removal
        b. Removal for major repairs
    2. Inspection of assemblies to determine cause of failure
    3. Reassembly and installation procedures

Teaching Suggestions

Emphasize the care that should be exercised when working in gearboxes, or with gears which may have developed a wire edge caused from wear that can easily lacerate or scrape the skin. Also, point out the danger of mashing fingers, hands, or an arm, if the machine's gear train is caused to rotate.

Have the components being taught exposed in plain view of the student so he can see the movement of the parts. Cutaway components, or working models, as well as service manuals for the actual piece of equipment being taught are essential.

Student Assignments

Have each student adjust a steering clutch and brake that have been misalined. Score him in practical application.

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Have each student disassemble, clean, inspect, reassemble, and adjust backlash of a differential.

References

Crouse. *Automotive Mechanics*, chapter 28, pp. 591–601.

Unit IX

PRINCIPLES OF HYDRAULICS

Training Time

Classroom, 20 hours; shop, 10 hours

Objectives

To develop an understanding of hydraulic fundamentals of transmitting force to do work, and provide practical exercises in computing pressure and force.

To acquaint the students with techniques used, and advantages gained, under certain applications of hydraulics, plus the flexibility of the systems.

Unit Outline

A. Safety factors—invite a guest speaker from industry
   1. Advantages gained through hydraulics
   2. Increasing use of hydraulics
B. Basic hydraulic theory
   1. Fluid characteristics
      a. Flexibility
      b. Fluid in motion with no resistance to flow
      c. Fluid in motion with resistance to flow
      d. Pascal's Law
   2. Fluid selections
      a. Flat viscosity oils
      b. Temperature effects on oil
      c. Chemical reactions of heat and foreign matter
C. Basic hydraulic principles
   1. Power transmission with fluids
   2. Design factors for job types
      a. Simplex system
      b. Reciprocating systems
      c. Rotating systems
D. Cleanliness
   1. Strainers
   2. Filters
   3. Schedule of oil changes
E. Related physics for basic hydraulics
   1. Static pressure
   2. Hydraulic forces
      a. Linear force
      b. Rotary force or torque
      c. Principles to control speed and power
      d. Total working force
      e. Differential area
      f. Effects of atmospheric pressure

Teaching Suggestions

Principles of hydraulics taught through the use of working models as training aids, from the very simple to the complex, give the student an understanding he can appreciate when troubleshooting systems of hydraulic units installed on heavy construction equipment.

Included with this unit are some illustrations from which transparencies can be made for classroom use with an overhead projector.

Use a hydraulic jack to develop an experiment by measuring the length of the jack handle to determine foot-pounds of force applied to lift an extremely heavy load of known weight.

Student Assignments

Establish hypothetical situations, giving the fluid pressure in pounds per square inch and pistons of various diameter, for the student to determine the total working force developed at each piston (see Figure 3B).

References

Nichols. *Heavy Equipment Repair*, chapter 9, pp. 255–267.

Oster. *Basic Applied Fluid Power*.

Films

Principles of Fluids, Society for Visual Education.

Unit X

HYDRAULIC SYSTEMS

Training Time

Classroom, 30 hours; shop, 30 hours

Objectives

To develop the student's understanding of the power flow and action of components in hydraulic systems.

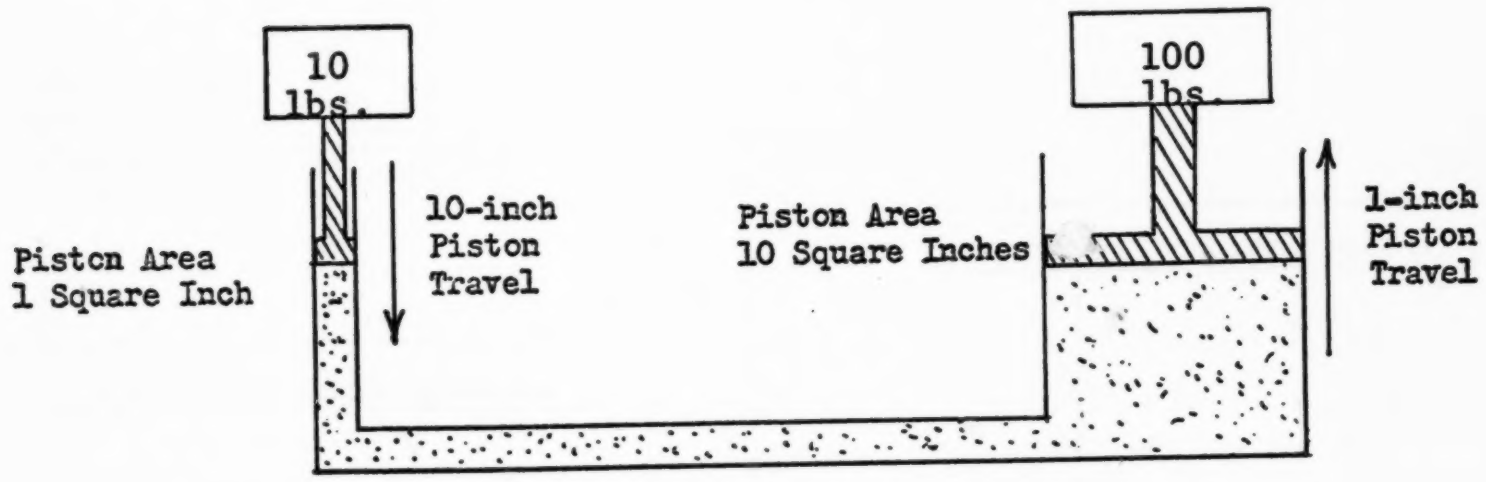

Figure 3. Hydraulic cylinder and differential area principles.

Will the Piston Move?

Yes! With a Force of 314 Pounds

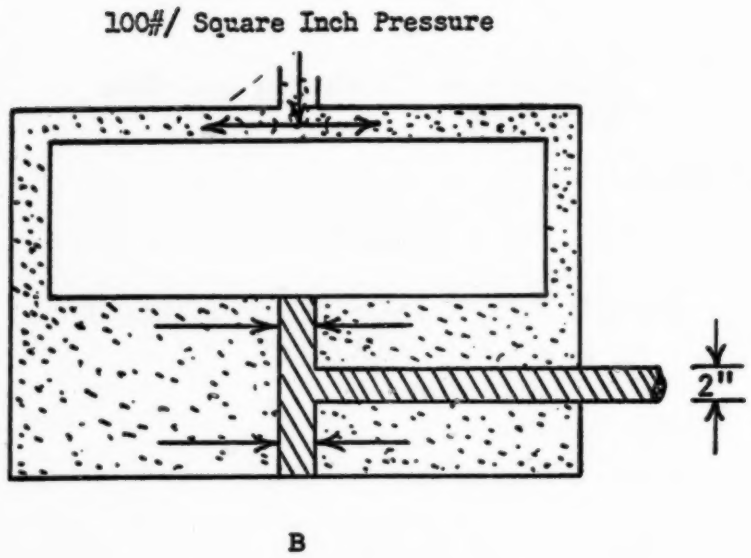

Figure 4. Effect of atmospheric pressure on mercury.

To develop the student's ability to repair valves, and to understand the application of valve types and how they function in heavy construction equipment hydraulic systems.

To develop the student's ability to repair pumps, understand the application of pump types, and acquaint them with the principles of using pumps and motors.

Unit Outline

A. Safety factors
   1. Precautions for handling slick or oily equipment components
   2. Precautionary measures to prevent equipment damage

B. Control valve fundamentals
   1. Valve types and applications
      a. Gate and check
      b. Globe and needle
      c. Rotary cock
      d. Spool
   2. Special valves
      a. Unit control valves
      b. Control valve banks or manifolds
      c. Open-and-closed center valves

C. Pump and motor fundamentals, failure analysis, and repair
   1. Auxiliary pumps
      a. Reciprocating
      b. Centrifugal
      c. Diaphragm
   2. Gear type pumps
      a. External gear
      b. Internal gear
      c. Gerotor gear
      d. Screw
   3. Vane-type pumps
      a. Fixed rotor
      b. Balanced rotor
      c. Variable delivery
   4. Radial piston-type pumps
      a. Fixed delivery
      b. Variable delivery

D. Related science
   1. Effects of heat on fluids
   2. Heat exchangers
   3. Centrifugal forces
   4. Closed systems

E. Filters and strainers

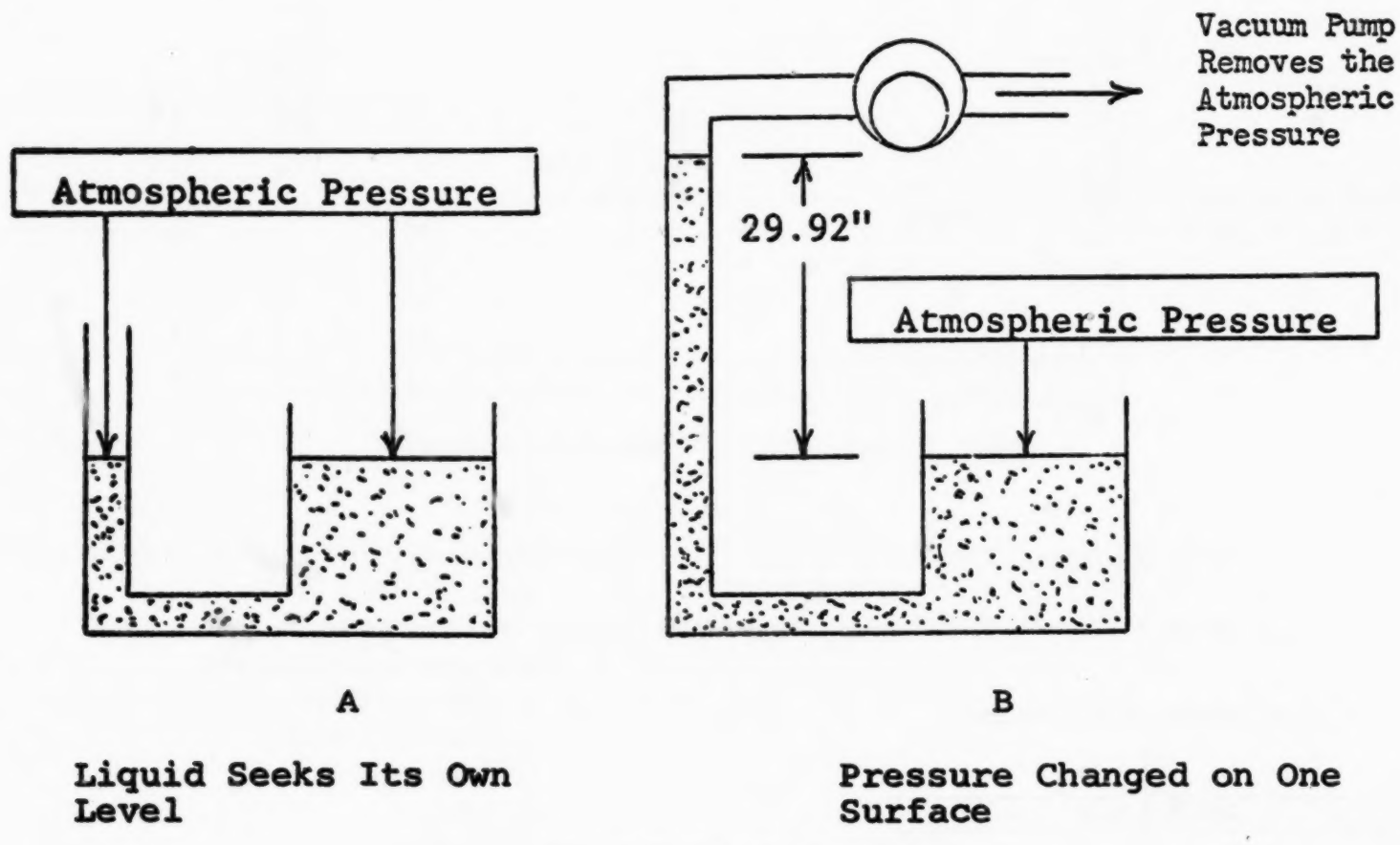

Figure 5. Control valve flow path.

Teaching Suggestions

Display the valve, pump, or motor that is being taught. Start the instruction with the unit disassembled, explaining nomenclature and relation of parts as reassembly is completed. Then, with a working model, demonstrate the unit in operation.

Emphasize techniques required because of the close tolerances necessary for satisfactory performance of the hydraulic components used on heavy construction equipment. Demonstrate the sequence for torquing pump cases and side plates.

Student Assignments

Have student team disassemble, describe the functions of the parts, and reassemble each of the following: check valve, needle valve, gate valve, gear pump, vane pump, and a radial piston pump.

References

Nichols. *Heavy Equipment Repair*, chapter 9, pp. 255–267.

Oster. *Basic Applied Fluid Power*.

Films

Principles of Fluids. Society for Visual Education.

Unit XI

FLUID COUPLINGS AND TORQUE CONVERTORS

Training Time

Classroom, 20 hours; shop, 40 hours

Objectives

To develop student understanding of the principles of operation of the fluid coupling and the hydraulic principles applied in torque convertors.

To acquaint students with the nomenclature of fluid coupling and torque convertor components and develop their ability to repair them.

Unit Outline

A. Safety factors
   1. Personal safety
      a. Working under heavy equipment
      b. Removing heavy components from under equipment
   2. Equipment protective measures
      a. Use of transmission jacks
      b. Use of stands under heavy equipment

B. Principles of fluid coupling operation
   1. Nomenclature
   2. Pump or driving member
   3. Driven member and components
   4. Fluid flow
      a. Low and high vortex
      b. Zero vortex
   5. Advantages of fluid coupling
      a. Sudden change of load
      b. Engine performance

C. Principles of torque convertor operation, and fluid flow
   1. Nomenclature
   2. Pump purpose
   3. Turbine operation
   4. Fluid flow through turbine and stator
   5. Principle of the hydraulic retarder

D. Troubleshooting
   1. Inspection and analysis
   2. Repair and replacement

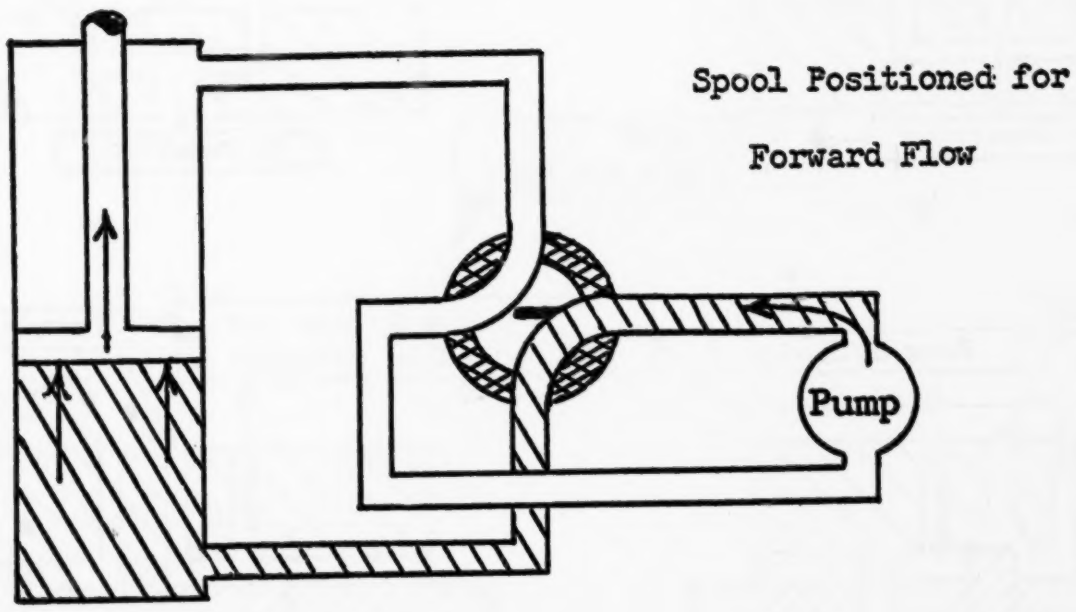

Figure 6. Gear pump.

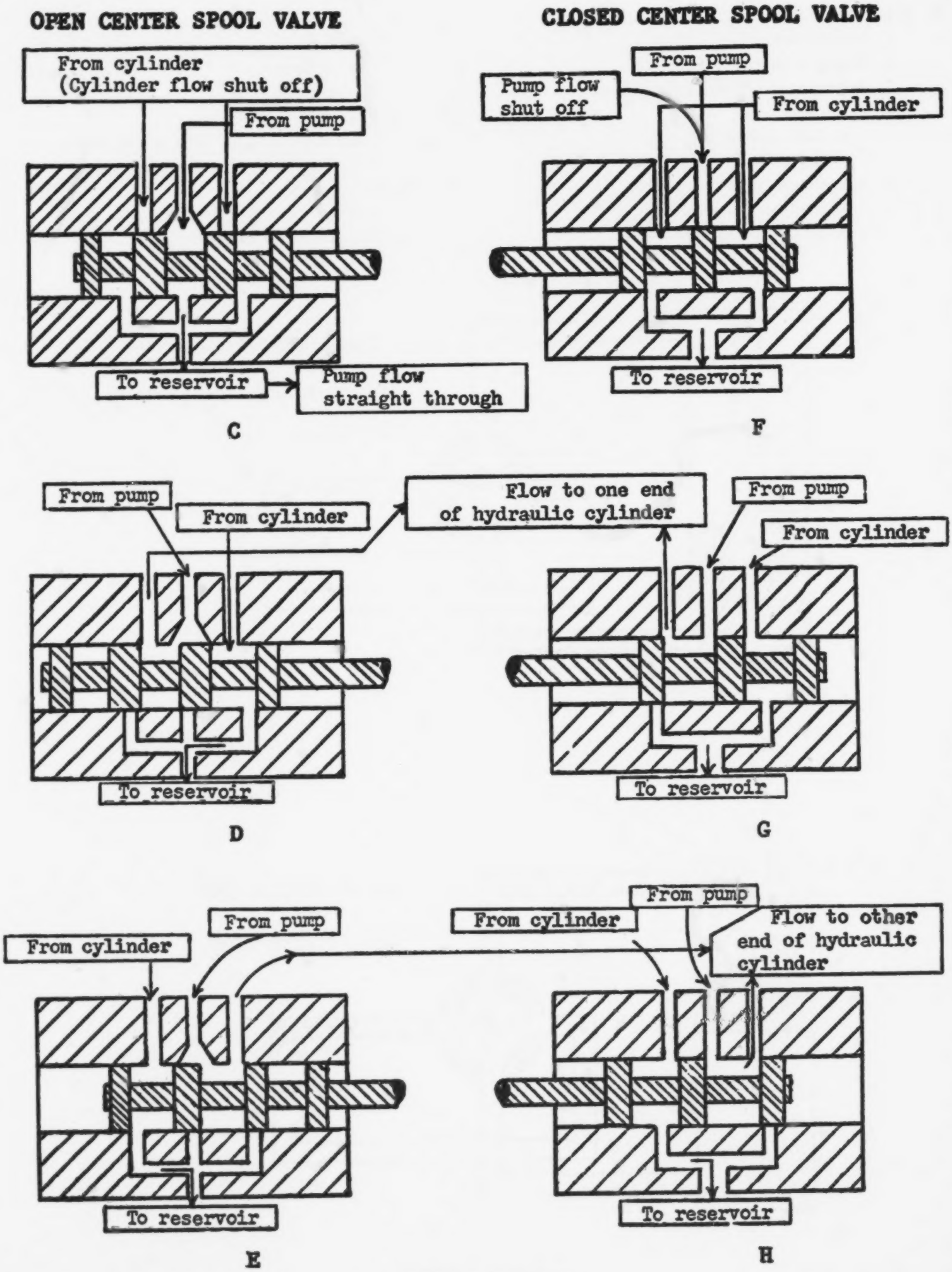

Figure 7. Vane pump.

E. Related science
    1. Definition of work
    2. Definition of torque
    3. Principles of torque reduction and multiplication
    4. Efficiency loss through heat

Teaching Suggestions

Emphasize the importance of a thorough knowledge and understanding of the principles of operation of the fluid coupling and the torque convertor.

Demonstrate disassembly of the units as the presentation is made to the class, defining each of the components as discussion progresses. Repeat the presentation of the components, encouraging class participation, then reassemble the unit as the instructional phase is completed.

Student Assignments

Have student team disassemble, name, and describe the operation of each component; then have them reassemble a fluid coupling and a torque convertor.

References

Crouse. *Automotive Mechanics*, chapter 24, pp. 486–574.

International Harvester, Construction Equipment Division. *Torque Convertors CT–25.*

Nichols. *Heavy Equipment Repair*, chapter 6, pp. 184–198.

Oster. *Basic Applied Fluid Power.*

Texaco Library of Technical Aids. *Operation and Care of Hydraulic Machinery.*

Unit XII

AUTOMATIC TRANSMISSIONS

Training Time

Classroom, 30 hours; shop, 60 hours

Objectives

To develop the student's understanding of the principles of automatic transmission control systems and power flow—their functions, operation, and hydraulic actions throughout the power flow.

To develop the student's ability in troubleshooting, inspecting, adjusting and servicing heavy construction equipment automatic transmissions.

Unit Outline

A. Safety factors
    1. Personal
        a. Removing retaining rings
        b. Opening spring loaded components
    2. Equipment
        a. Use of guide bolts
        b. Alinement of components

B. Nomenclature and operation of automatic transmission
    1. Hydraulic operation
        a. Control valves
        b. Fluid flow
    2. Speed and direction flexibility
    3. Size and identification codes
    4. Components of the transmission
    5. Power flow
    6. Quadrant and position linkage
        a. Reverse position
        b. Speed range positions
        c. Automatic shifting
        d. Load factors for range selections
    7. Governors
    8. Servo pumps

C. Troubleshooting
    1. Inspection and analysis
    2. Specifications and adjustments
    3. Testing

Teaching Suggestions

Explain need for close attention by students, because transmissions are very complex, and yet not *complicated* if each component is understood. Explain similarity of transmissions, but point out differences after each type has been taught.

Point out the need for strict adherence to the manufacturer's service manual for servicing the specific transmission being worked on. Provide students with diagram of powerflow for the unit being taught.

Note: See appropriate service manual for type transmission available at training facility. Provide sufficient copies.

Student Assignments

Have student team trace the powerflow of each transmission taught, using appropriate service manual, and explain each operation.

Have each student team disassemble, inspect, clean, reassemble, and adjust an automatic transmission.

References

Crouse. *Automotive Mechanics*, chapter 26, pp. 578–581.
Nichols. *Heavy Equipment Repair*, chapter 7, pp. 213–215.
International Harvester, Construction Equipment Division. *Power Shift Transmission CF–26.*

Unit XIII

BRAKE AND BOOSTER SYSTEMS

Training Time

Classroom, 30 hours; shop, 60 hours

Objectives

To develop the student's understanding of brake systems used in heavy construction equipment.

To develop the student's skill in analyzing brake systems and making repairs and adjustments.

Unit Outline

A. Safety factors
    1. Safety chairman of Operation Engineers speaks on "Brake System of Construction Equipment"
    2. Safety film related to brakes
        a. Roll of drums
        b. Film selected by guest speaker
B. Operating principles of friction brakes
    1. Definition of a brake
    2. Types of brakes
        a. External contracting
        b. Internal expanding
        c. Disc
    3. Wear limits, repair, and adjustments
C. Nomenclature of external contracting brakes
    1. Drum surfaces
    2. Contracting band assembly
        a. Lining materials
        b. Methods by which lining is secured to band
    3. Arrangement of operating mechanisms
        a. Winch arrangements
        b. Boom equipment arrangements
        c. Pedal and lever-operated arrangements
        d. Final drive, axle mounted arrangements
D. Nomenclature of internal expanding brakes
    1. Drum surfaces
    2. Expanding brake shoe assembly
        a. Brake shoe materials
        b. Methods through which brake shoes are secured to lining materials
        c. Methods through which brake shoes are mounted to back plate
    3. Arrangement of operating mechanisms
        a. Shoe hinges
        b. Floating shoe links
        c. Wheel cylinders
        d. Cam arrangements or mechanical brakes
        e. Hydraulic brake wheel cylinders
        f. Compressing, or return springs
E. Nomenclature of disc brakes
    1. Anchored and rotating plates
    2. Lined or unlined discs
    3. Operating mechanisms
F. Types of brake control stations
    1. Hydraulic master cylinders
    2. Vacuum and vacuum boosters
    3. Air over hydraulic systems
    4. Air brake systems
    5. Electric brake systems
G. Nomenclature of control stations
    1. Hydraulic brake master cylinders
    2. Vacuum brakes
        a. Slave cylinder, piston, and valves
        b. Vacuum cylinder, piston, and proportioning chamber
    3. Air brakes
        a. Reservoirs
        b. Brake chambers
        c. Brake valve or treadle valve
H. Electric brakes
    1. Solenoids
    2. Rheostat
I. Brake system schematics

Teaching Suggestions

Stress working from service manuals and schematics to tie units into a system.

Use cutaways of units used in the systems, or, if using actual equipment, then start the instruction with the units disassembled. Teach nomenclature. Principles of operation will then be understood more readily.

Student Assignments

Have the students draw a schematic of a basic brake system, one which they have studied, of course; and have them name the components of the system.

Have the students sketch and describe the operating principles of an external contracting brake, an internal expanding brake, and a disc brake; then have them name at least one application where each type is used.

Have student teams turn a scored brake drum, measure it for amount of cut from standard, shim the brake shoes to compensate, and reassemble and adjust the brake.

References

Crouse. *Automotive Mechanics*, chapter 32, pp. 668–691.

Nichols. *Heavy Equipment Repair*, chapter 8, pp. 233–248.

Unit XIV

ACCESSORY CASE ENGINE DRIVEN AIR COMPRESSORS

Training Time

Classroom, 10 hours; shop, 20 hours

Objectives

To develop the student's understanding of air compressors used in heavy construction equipment systems.

To develop the student's ability to analyze failures in the air compressor installations, and to remove and repair or replace faulty components.

Unit Outline

A. Safety factors—personal
   1. Eye protection
   2. Hazards of ruptured lines "flapping," or being struck by air stream

B. Principles of air compressors
   1. Single-stage compressors, reciprocating
      a. Intake air filters
      b. Intake valves
      c. Discharge valves
      d. Unloader valves and air governors
      e. Lubrication principles
      f. Compressor mounts and piping
   2. Air reservoir
      a. Bottom drain or blow-down procedure
      b. Gauges and pressure controls

C. Troubleshooting
   1. Failure analysis
   2. Repair and adjustment

Teaching Suggestions

Make the comparison of air compressors to the intake and compression stroke of a four-cycle engine and to the intake and compression cycle of air compressors; then explain the principles of check valves used in air compressors.

Student Assignments

Have student teams remove the suction and discharge valves from a reciprocating air compressor, explain the principles of their operation, and reinstall them.

Have student team test the relief valve and drain condensate from the air reservoir.

References

Nichols. *Heavy Equipment Repair*, chapter 20, pp. 553–570.

Unit XV

MACHINERY DECK-BOOMS AND ATTACHMENTS

Training Time

Classroom, 20 hours; shop, 40 hours

Objectives

To develop the student's knowledge of heavy construction equipment principles of operation covering turntables, deck machinery, boom arrangements for cranes, clamshells, draglines, dipper shovels, and backhoes.

To develop the student's knowledge of the principles of servicing and/or repairing winches, and of the equipment used in these machines; and of the proper method of reeving cables, or rigging hydraulic units on winches.

Unit Outline

A. Safety factors
   1. Faulty brake or clutch
   2. Engaging of safety locks
   3. Proper use of jack frames
   4. Cable handling

B. Machinery deck
   1. Turntable
      a. Swing rollers
      b. Hook rollers

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c. Ring gear
d. Swing shaft and gear

2. Deck base structures
a. Boom foot brackets
b. Engine base
c. Winch bases
d. Operator's station
e. Roller brackets
f. Counterweights

C. Winches and control principles
1. Planetary winch
a. Ring gear and brake
b. Planetary brake
c. Principles of spooling in, and paying out, winch equipment

2. Winch equipment and arrangements
a. Swing and propel power flow
b. Power flow for
(1) Boom hoist
(2) Hoist
(3) Crowd-retract
(4) Digging, drag, or closing
c. Driving sprockets
d. Idler sprockets
e. Bevel gears
f. Angle or silent chain drives
g. Operator's station
(1) Linkage controls
(2) Hydraulic controls
(3) Electrical controls
h. Drum lagging
i. Fairleads and fairlead brackets

D. Boom and attachment principles
1. Cranes
a. Types of booms used and base mounts
b. Sheaves, blocks, and traveling blocks
c. Hooks
(1) Safety snap
(2) Swivel hook
(3) Eye-hook and reversed eye-hook
d. Jib boom and gantry

2. Clamshell
a. Types of booms and base mounts
b. Cable arrangements
(1) Boom line
(2) Hoist line
(3) Digging line
(4) Tag line
c. Clamshell operation
(1) Center pull bucket
(2) Lever arm bucket
(3) Tong grapples
d. Capacity rating

3. Dipper shovel
a. Types of booms used and base mounts
b. Dipper stick
c. Saddle block
d. Cable arrangements
(1) Boom hoist cable
(2) Hoist line
(3) Dump line
(4) Crowd chain
e. Bucket operation
(1) Pitch brace
(2) Bucket sheave
(3) Lip, socket, and teeth of buckets

4. Backhoe or pull shovel
a. Types of booms used and base mounts
b. Jack-boom and gantry
c. Hoe stick
d. Hoe bucket
(1) Pitch brace
(2) Hydraulic ram control

5. Dragline
a. Types of booms used and base mounts
b. Cable arrangements
(1) Boom cable
(2) Hoist cable
(3) Drag cable and chains
(4) Dump cable

6. Changing booms
a. Removing boom
b. Walking the machine with boom removed, but with counterweight still mounted
c. Cable reeving
d. Drum lagging changes to make rigging changes

7. Principles of fluid couplings or torque convertors on engine drives

Teaching Suggestions

Develop a working model to demonstrate booms, cable reeving, and the principles of winch operation in heavy construction boom equipment. Rig to demonstrate the principles of jib booms and gantry.

Remove fairings and demonstrate on the actual machine the principles of operation of each component and the power flow for each drum.

Demonstrate adjustments and procedures on the controls; also, how to follow the manufacturers' instructions as given in service or operator's manuals.

Student Assignments

Have each student reeve the working model for each type attachment.

Misaline the controls on a piece of equipment and have each student readjust them.

Have each student remove a clutch or a brake, replace it, and make the proper adjustments.

References

Nichols. *Heavy Equipment Repair*, chapter 19, pp. 493–550.

Unit XVI

FUNDAMENTALS OF PISTON PUMPS AND PUMP SYSTEMS

Training Time

Classroom, 20 hours; shop, 40 hours

Objectives

To develop the student's understanding of axial piston hydraulic systems—their application, operation, how to analyze malfunctions, and how to service them properly.

To acquaint students with high pressure hydraulic propel systems, the infinite speed selections of which they are capable, and the nomenclature of the components used to achieve these functions.

Unit Outline

A. Safety factors
   1. Personal safety
      a. Precautions for working around high pressure hydraulic liquids
      b. First aid
   2. Equipment safety
      a. Clean working habits
      b. Filters and strainers

B. Axial piston pump principles
   1. Pump nomenclature
      a. Stationary barrel, swash plate drive
      b. Rotating barrel, in line, and angle to drive shaft
   2. Pump principles
      a. Body designs
         (1) Valve plate arrangements
         (2) Double, inverse relief valve
         (3) Transmission line arrangements between pump, and a similar pump used as a hydraulic motor
      b. Principles of moving parts
         (1) Fixed and variable angle swash plates
         (2) Pistons, connecting rods, and methods of securing the ends of each
         (3) Double universal joints, and their application
         (4) Means of securing moving parts to rotate together; and the purpose for having them rotate simultaneously
      c. Principles of stroking mechanisms
         (1) Mechanical principles
         (2) Servo pressures and hydraulic principles
         (3) Governor controls and hydro-mechanical principles

C. Operating pressure ranges
   1. Charging pressure and its purpose
      a. Static oil
      b. Free-flow oil
   2. High pressure oil
      a. In neutral position
      b. In forward motion position
      c. In reverse motion position
   3. Expansion tank, or reservoir
   4. Filters
   5. Coolers—liquid and air

Teaching Suggestions

Use a cutaway of the variable delivery pump to show how the pump can rotate at constant speed, yet pump liquids in either direction from maximum output to zero output, simply by the amount of angle put on the swash plate. Have the valve plate and ports exposed to the class during demonstration, and refer to it when explaining fluid flow without changing the direction of input shaft rotation.

Show students that the fixed angle of pumps, or of motors, is the only major difference between constant speed, variable delivery, axial piston pumps, and fixed delivery pumps, or motors.

Explain the principle of why relief valves are needed to relieve excessive pressure from either transmission line, inasmuch as either of the lines can be the high pressure line under forward or reverse operating conditions.

Student Assignments

Have student teams explain the flow of fluid through the constant speed, variable delivery, axial piston pump in the forward and reverse flow.

Have student teams disassemble the components of the constant speed, variable delivery, axial piston pump and reassemble them.

Have student teams disassemble the valve plate relief valves and reassemble them.

References

International Harvester, Construction Equipment Division. *Basic Hydraulics TE-6.*
Oster. *Basic Applied Fluid Power.*

Unit XVII

BATTERIES AND FUNDAMENTALS OF ELECTRICITY

Training Time

Classroom, 18 hours; shop, 6 hours

Objectives

To acquaint the student with the characteristics of wet cell batteries and to develop his ability to work safely with them.

To develop the student's understanding of the theories and principles of magnetism and magnetic induction associated with electrical equipment common to heavy construction equipment.

Unit Outline

A. Safety factors
   1. Personal safety
      a. First aid for acid on skin or in eyes
      b. First aid for burns, flash or acid
   2. Equipment protection
      a. Steps to take before checking batteries
      b. Precautions prior to installing or removing battery

B. Wet cell storage battery
   1. Definition of a storage battery
   2. Principles of a wet cell battery
      a. Basic construction
      b. Dry charged battery
      c. Adding electrolyte to battery
      d. Temperature effects on battery efficiency
      e. Battery tests to be made
         (1) Gravity check
         (2) Cell check
         (3) Load and light tests
         (4) Checks for loose connections
      f. Charging batteries
         (1) Types and use of chargers
         (2) Single unit
         (3) Charging two or more batteries simultaneously
      g. Battery specifications
      h. Battery polarity
      i. Booster cables

C. Fundamentals of electricity—magnetism and magnetic induction
   1. Natural magnets
   2. Magnetic lines of force around a bar magnet
   3. Electromagnets
   4. Ignition coils and polarity effects
   5. Conductor sizes
   6. Ohm's law
   7. Current induction—DC generators
   8. Current induction—alternators
   9. Variable rheostats
   10. Electrical circuits

Teaching Suggestions

Explain that current passing through electrolyte generates hydrogen, an explosive gas, which if ignited would blow electrolyte on anyone near. Teach first aid for this and warn students to be careful.

Develop breadboard training aids to instruct electrical circuits, hook the components of typical systems into the circuit, and then let the students practice assignments on them.

Cut open a good quality battery and a poor quality battery, and explain the differences to the students.

Student Assignments

Have student teams take gravity readings from all the cells of a battery and correct them for temperature to determine the condition of the battery.

Have student teams remove a battery from a piece of equipment, charge it with one or more batteries on the same charger, and reinstall it.

Have student teams build a series, a parallel, and a compound circuit on breadboards.

References

Crouse. *Automotive Mechanics*, chapter 7, pp. 151–155.
Nichols. *Heavy Equipment Repair*, chapter 5, pp. 149–167.

Films

Electrical Magnets. Society for Visual Education.
Permanent Magnets. Society for Visual Education.

Unit XVIII

FUNDAMENTALS OF ELECTRIC STARTING MOTORS AND GENERATORS

Training Time

Classroom, 15 hours; shop, 45 hours

Objectives

To acquaint the student with the principles of using energy from the storage battery to create magnetic torque in the starting motor to provide mechanical force for the starting of the engine, and develop his understanding of current induction.

To develop the students' ability in failure analysis of heavy construction equipment electrical systems and make repairs or replacement of parts, and adjustments using electrical measuring devices.

Unit Outline

A. Safety factors
    1. Personal safety
        a. First aid for electrical burns
        b. Eye first aid for electrical flash
    2. Equipment protection
        a. Improper connections
        b. Accidental grounding with metal tools
B. Starting motors and generators
    1. Nomenclature and operating principles
        a. Drive or bendix
            (1) Types of bendix
            (2) Applications
        b. Case
            (1) Types of starters
            (2) Field coil arrangements
        c. Armature and commutators
            (1) Types of armatures
            (2) Principles of magnetic torque
        d. Brushes and end frames
            (1) Starters
            (2) Generators
        e. Solenoids
            (1) Types of solenoids
            (2) Linear force
    2. Operating principles of DC generators
        a. Induction of current in loop or armature coil, rotated in a magnetic field
        b. Brush and commutator relationship
        c. Rate of armature rotation and field coil strength
        d. Generator pulley, fan, and air circulation
        e. Polarizing the generator
        f. External and internal grounded generators
        g. Third brush generators
    3. Operating principles of alternators
        a. Front housing, fan, and pulley
        b. Rear housing and terminal locations
        c. Stator core and coil assembly
        d. Stator winding
            (1) Types of windings
            (2) Diodes and diode construction
        e. Rotor core and coil assembly
        f. Brushes and brush holders
        g. Rectifier assembly
            (1) Field excitation
            (2) Internal circuitry
    4. Trouble shooting
        a. Starting motors
        b. DC generators
        c. Alternators

Teaching Suggestions

Use charts or slide projections to teach theory of magnetism. Explain that magnetism is the connecting link between electrical and mechanical energy.

Start demonstrating with a solenoid, compare it to the electromagnet. Then advance into the principles of magnetic torque in motors as being the same, except as a rotary force.

Begin generator instruction by calling attention to the similarity of inducing current into the conductors. Point out that the loop, or coil, is the conductor interrupting the magnetic lines of force.

Explain the diode, or rectifier, and compare the differences between the DC generator and the alternator.

Student Assignments

Have student team disassemble, make tests of the armature, field coils, brush holders, and bearings; then reassemble and check the generator.

Have student team repeat the same steps with an alternator, plus removing and replacing one negative and one positive diode.

References

Crouse. *Automotive Mechanics*, chapter 7, pp. 141–169.
Nichols. *Heavy Equipment Repair*, chapter 5, pp. 155–166.

Unit XIX

ELECTRICAL REGULATORS AND CONTROLS

Training Time

Classroom, 15 hours; shop, 45 hours

Objectives

To acquaint the student with the theories of current and voltage regulators in DC and alternator systems. To develop the student's ability to make the proper connections with instruments—test, adjust, and service the systems as installed on heavy construction equipment.

To develop the student's understanding of the operating principles of relays, switches, and other components in electrical generating, starting, and lighting circuits; develop his ability to analyze failures and correct them.

Unit Outline

A. Safety factors
    1. Personal safety
    2. Precautions to protect the equipment
B. Components of the DC charging system
    1. Generator
    2. Regulator—containing the relay, voltage regulator, and current regulator
    3. Ammeter
    4. Battery
C. Electrical system schematics
    1. Component symbols
    2. How to read circuits
    3. How to make schematics
D. Principles of DC generator regulation
    1. Effects of battery condition
        a. Current regulator operation
        b. Speed of DC generator
    2. Cut-out relay principles of operation
        a. Location and the part it plays in a regulator
        b. When battery voltage is greater than generator voltage
        c. When generator voltage is greater than battery voltage
    3. Principles of the voltage limiter
        a. Relation of voltage limiter to the generator field
        b. Location of the voltage limiter in the regulator
        c. Principles of voltage limiter operation
            (1) With no load
            (2) With a very light load
            (3) With a heavy load
        d. Voltage limiter circuit
    4. Principles of the current limiter
        a. Relation of the current limiter to the battery and load demand from lights, etc.
        b. Location of the current limiter in the regulator
        c. Principles of current limiter operation
            (1) With no load and with battery fully charged
            (2) With battery low and no load
            (3) With battery charged and a light load
    5. Current limiter circuit
E. Principles of alternator regulation
    1. Effects of battery condition
        a. With a dead battery
        b. With a low battery
        c. With a fully charged battery
    2. Components of alternator regulators
    3. Principles of alternator field relay in three-unit regulators
    4. Principles of voltage regulation
    5. Principles of current regulation
F. Failure analysis
    1. Schematic reading
    2. Component control reactions

Teaching Suggestions

Teach components of the entire charging systems, defining their relation in the overall circuit. Then, with a regulator in an operating laboratory mock-up, demonstrate how the regulator components affect the DC generator output. Repeat the same teaching process with alternator circuits; then develop the student's ability to work with, and to understand, schematics.

Disassemble; explain the components of a DC generator regulator; reassemble and operate in a charging system, making proper adjustments and instrument hookups. Repeat the process with an alternator.

Student Assignments

Have student team test and adjust a DC generator regulator, and explain each operation.

Have student test and adjust an alternator regulator, and explain each operation.

Have student team make a schematic of a complete alternator charging system.

Reference

Crouse. *Automotive Mechanics*, chapter 7, pp. 166–177.

Films

Electrical Circuits. Society for Visual Education.
Principles of Electrical Motors and Generators. Society for Visual Education.

Unit XX

WELDING FUNDAMENTALS

Training Time

Classroom, 15 hours; shop, 45 hours

Objectives

To develop the student's ability to accomplish convenience applications of arc welding jobs in the performance of his repair assignments. To develop sufficient skill to set heat ranges, select the correct electrodes, and make acceptable tack welds or braces.

To develop the student's ability to properly light and adjust oxyacetylene torch equipment for burning, welding, soldering, brazing; to heat metals used in the construction of heavy construction equipment; to bend, to free seized parts; to fit structural parts together; or to perform other jobs required in servicing or repairing the equipment.

Unit Outline

A. Safety factors
    1. Personal safety
        a. First aid for burns
        b. First aid for ultra-violet, flash burns
        c. First aid for electric shock
    2. Storage of equipment
    3. Laying out cables to the job
B. Electric arc welding
    1. Special rods and metals
        a. For building up surfaces
        b. For holding strength
    2. Universal rods
        a. All purpose rods, ferrous metals
        b. All purpose rods, nonferrous metals
    3. Welding machine types
        a. DC arc welding machines
            (1) DC generators
            (2) Rectifier machines
        b. AC arc welding machines
            (1) Transformers, welding
            (2) AC motor generators
            (3) Low frequency welders
            (4) High frequency welders
        c. Resistance welding machines
            (1) Spot
            (2) Butt
            (3) Flash
            (4) Projection
            (5) Seam
C. Oxygen-acetylene equipment
    1. Welding, soldering, or brazing
        a. Adjusting torch for applications
        b. Regulators and bottle storage
    2. Oxyacetylene cutting
        a. The cutting torch
        b. The cutting process
D. Inert gas arc welding—inert gas welding machines
    1. Types of electrode applications
    2. Types of inert gas used and amounts
E. Principles of welding and cutting
    1. Oxyacetylene welding theory and practice
    2. Oxyacetylene cutting theory and practice
    3. DC welding theory and practice
    4. AC welding theory and practice
    5. Electric resistance welding theory and practice

Teaching Suggestions

Emphasize safety in the operation of all welding equipment, not only because it can cause fatal electrical shock, but because there can be burns and flashes harmful to the eyes. Teach safety in spaces where the equipment is used—spaces containing gas that can be ignited, spark ignitable rags, or other combustibles are also dangerous.

Demonstrate laying out, cutting, and welding to the students; then have them repeat each of the assignments for each type of welding until they become proficient. Devise a means of testing the welds—pressure or break tests.

Student Assignments

Have each student practice oxyacetylene brazing.

Have each student practice flat and vertical arc welds.

Reference

Nichols. *Heavy Equipment Repair*, chapter 12, pp. 319–332.

Unit XXI

UNDERCARRIAGE AND WHEELED VEHICLES

Training Time

Classroom, 30 hours; shop, 60 hours

Objectives

To develop an understanding of the carriage assemblies of heavy construction equipment.

To develop the student's ability to safely make repairs to carriage assemblies.

Unit Outline

A. Safety factors
   1. Personal safety
      a. Accident prevention
      b. First aid for injuries associated with this type of employment
   2. Equipment safety
      a. Accident prevention film
      b. Precautions for equipment disassembly and reassembly

B. Wheeled vehicles
   1. Self-propelled
   2. Mobile
   3. Scrapers
      a. Frame design principles
      b. Hydraulic attachment mounting principles
      c. Fixed pivots, pad eyes, and principles of chassis operation
   4. Off-the-road haulers
      a. Reversed tractor
      b. Two-wheel tractors
      c. Four-wheel drive tractor, dozer, and loader
      d. Pivot-steered tractor

C. Crawler carriages
   1. Draw equipment
      a. Center section or chassis
      b. Track frames and rollers
      c. Dead axle
      d. Drawbar
      e. Tracks, track wheels, and track chain sections
   2. Dozers and loaders
      a. Tractor frame
      b. Push arm
      c. Pitch arm and angle arms
      d. Loader frame, cross beam, dump arm, and rams

D. Outriggers
   1. Manual
   2. Hydraulic

E. Troubleshooting
   1. Wheel vehicles
      a. Steering
      b. Chassis
   2. Crawlers
      a. Tracks and track rollers
      b. Alignment
   3. Inspection points and wear limits
   4. Build up by welding, etc.

Teaching Suggestions

Define the types of carriages to familiarize the students with the heavy construction equipment undercarriages used. Use pictorials, strip film, motion pictures, and overhead projectors to describe universal carriages, and then to show their special popular applications.

Student Assignments

Have two-man teams work together. Have each team work on opposite sides of a piece of equipment (wheeled and crawler), to disassemble and reassemble.

Reference

Nichols. *Heavy Equipment Repair*, chapter 17, pp. 419–491.

Unit XXII

LUBRICATION

Training Time

Classroom, 10 hours; shop, 20 hours

Objectives

To acquaint the student with techniques and principles of lubricating heavy construction equipment; and to develop his ability to properly schedule and perform preventative maintenance on the equipment.

Unit Outline

A. Safety factors
   1. Personal safety
      a. Precautions to take when dragging lines where footing is precarious
      b. Precautions to practice when handholds and equipment are made slippery by oil and/or grease
      c. Do not lubricate a machine in motion
   2. Equipment safety
      a. Precautions to take to prevent machines from getting into motion
      b. Precautions to practice to avoid releasing winch brake, etc.

B. Lubricants specified
   1. Manufacturers' specified lubricants
   2. Lubrication programs
      a. Schedule
      b. Policies

C. Types of lubricants and their applications
   1. Heavy adhesive residual lubricants for open gears
      a. Straight mineral oil
      b. Compounds
      c. Cut with solvents
      d. Extreme pressure
   2. Universal lubricants for open and closed gears
   3. Intermediate viscosity lubricants for closed gears
      a. Straight mineral oil
      b. Mineral oil with polar additives
      c. Theory of polar lubrication
      d. Extreme pressure oils—mild and active
      e. Theory of extreme pressure lubrication
      f. Extreme pressure additives

D. Methods of lubricant application
   1. Manual
      a. Paddle
      b. Hand
      c. Drip
      d. Brush
      e. Pouring
      f. Bath
   2. Mechanical
      a. Idler gear
      b. Circulating system
      c. Spray system
      d. Centralized

E. Lubrication charts
   1. Schematic reading
      a. Assemblies
      b. Piping shown on schematics
      c. Hollow shaft passages shown on schematics
   2. Manufacturer's operating manuals
      a. How to follow service instructions
      b. How one chart may apply to several similar types of equipment, and methods of depicting exceptions

F. Seals
   1. Types of seals
   2. Installation procedures
   3. Keeping oil in and dirt out

Teaching Suggestions

Make handouts covering types of lubricants and their applications that correspond to heavy construction equipment for students to use in the absence of manufacturer's instructions.

Get multiple copies of a manufacturer's maintenance lubrication schedule, and reproduce it in quantity to pass a copy to each student; then teach that particular schedule, preferably of a machine the students will be required to lubricate.

Student Assignments

Have each student use the proper devices, charged with the proper lubricant, and attach them to all of the points where the machine should be lubricated.

Have the student explain what type of lubricant he is using, and why.

References

Crouse. *Automotive Mechanics*, chapter 17, pp. 411–415.
Nichols. *Heavy Equipment Repair*, chapter 2, pp. 40–70.

Unit XXIII

AIR CONDITIONING

Training Time

Classroom, 20 hours; shop, 45 hours

Objectives

To acquaint the student with the theory and principles of air conditioning systems installed in heavy construction equipment.

To develop the student's ability to install, troubleshoot, and service air conditioning systems, and to use the special tools and gauges required in such servicing.

Unit Outline

A. Safety factors
   1. Personal safety
      a. Eye protection in the handling of refrigerants
      b. First aid for areas of body frozen as a result of contact with refrigerants
   2. Equipment safety
      a. New equipment checks to make prior to starting the compressor
      b. Loss of compressor oil

B. Theory and principles of air conditioning
   1. Heat
      a. Nature of heat
      b. Heat measurement
   2. Air conditioning cycle
      a. Compression
      b. Condensation
      c. Expansion

C. Components of air conditioning systems
   1. Compressors
      a. Valves: charging, suction, discharge, and others associated with the compressor
      b. Piston: rings, crankshaft, head, connecting rods, etc., as related to refrigeration compressors
      c. Seals, gaskets, and packing
   2. Types of compressors, including hermetically sealed compressors
   3. Condensers
      a. Liquid cooled
      b. Air cooled
      c. Liquid receivers
      d. Dehydrators
   4. Expansion valves and other control devices, such as thermostats
   5. Evaporators or expansion coils

D. Installations of air conditioning systems on heavy construction equipment
   1. Compressor mounting
      a. Types of bases
      b. Electric clutches
      c. Belt-drive arrangements
   2. Condenser and liquid receiver locations
      a. Methods of mounting and bracing
      b. Protection of coils from missiles
   3. Evaporator and fan locations
   4. Tubing, hoses, and fittings
   5. Switches and wiring arrangements

E. Diagnosis procedures and repair
   1. Schematic reading
   2. Diagnosis sheet reading
   3. Electrical circuit diagnosis

F. Related physics
   1. Temperature/pressure relationship of refrigerants
   2. Problems of moisture in systems
   3. Condenser cleaning procedure and effects of dust insulation on condensers
   4. Leak detecting
   5. Refrigeration oil

Teaching Suggestions

Stress safety, issuing a special warning to students not to rub their eyes if struck by freon or other refrigerants.

Prepare schematics of the refrigeration cycle to use as handouts to students. Have them draw in the electrical wiring and control valves as learning progresses.

Use the actual equipment, when possible, for diagnosis and repair, so that the students can become familiar with the installations.

Student Assignments

Have each student draw in the wiring and control valves on a prepared block diagram handout.

Have student teams go through the steps of pumping down, charging, and servicing an air conditioning system.

Reference

Crouse. *Automotive Mechanics*, chapter 35, pp. 722–725.

Unit XXIV

INDUSTRIAL AIR COMPRESSORS

Training Time

Classroom, 20 hours: shop, 15 hours

Objectives

To develop the student's understanding of industrial air compressors used in heavy construction—how to operate, service, and repair them.

Unit Outline

A. Safety factors
   1. Personal safety
      a. Safety goggles
      b. Keep jet stream clear of personnel
   2. Precautions to take
      a. Air cleaners and filters
      b. Diesel factor of dust laden air and anti-explosion precautions

B. Operating principles and nomenclature of air compressor system
   1. Single-stage, reciprocating
      a. Intake and discharge valves
      b. Piston, piston rings, and connecting rod
      c. Cylinder block, cylinder head, and manifolds
      d. Crankshaft, main and connecting rod bearings
      e. Lubrication pump and oil passages
      f. Compressor bases and mounts
   2. Two or more stage, reciprocating
      a. Intake and discharge valves
      b. Inter-coolers and after-coolers
   3. Single-stage air compressors, rotary
      a. Compressor case and air passage
      b. Rotors and vanes
      c. Oil pump and nozzles
      d. Air accumulators and separators
   4. Two-stage rotary air compressors
      a. Compressor case and air passages
      b. Rotors and vanes
      c. Oil pump, piping, and separators
      d. Air accumulator and separators
   5. Controls
      a. Electrical controls
      b. Pneumatic controls
      c. Compound controls
      d. Schematic reading
      e. Manufacturers' instructions

B. 6. Piping systems in shops
      a. Condensate traps
      b. Accumulator tanks
      c. Types of quick connectors
      d. Air lines and fittings
   7. Prime power sources
      a. Electric
      b. Internal combustion
      c. Turbines
      d. Couplings, reduction gears, and alinement

Teaching Suggestions

In the instruction include schematics, electrical control circuits, and pneumatic controls.

Stress the importance of a clean air supply to the compressors and air coolers to keep compression heat problems at a minimum; and the importance of oil systems functioning properly since all of these factors contribute to diesel explosions in compressors.

Using the actual equipment, teach shaft alinement, all types of flexible couplings, and reduction gear drives common to industrial air compressors.

Student Assignments

Have each student team remove, inspect, replace, and adjust a compressor suction and discharge valve.

Have each student team disassemble, reassemble, and set the relief pressure of a relief valve.

Reference

Nichols. *Heavy Equipment Repair*, chapter 20, pp. 553–572.

Texaco Library of Technical Aids. *Compressor Lubrication.*

Unit XXV

INDUSTRIAL AND LABOR RELATIONS

Training Time

Classroom, 3 hours

Objectives

To acquaint the student with the duties industry may expect him to perform; obligations of employee to employer and vice versa.

To prepare the student for the labor market, and to acquaint him with labor relations existing in various geographical areas—local, national, and foreign.

Unit Outline

A. Safety factors
    1. Personal safety
        a. Careful work habits
        b. Proper attire
        c. Personal cleanliness
    2. Equipment care
        a. Well-organized tool habits
        b. Clean tools and personal equipment
        c. Work station cleanliness
B. Industry and the beginning mechanic
    1. Attitude
        a. Toward learning
        b. Toward fellow employees
        c. Toward supervisors
        d. Toward the business
        e. Toward shop and customer equipment
    2. Common shop provisions
        a. Special equipment and tools
        b. Shop uniforms
        c. Safety glasses
        d. Washroom and dressing areas
        e. Tool storage facilities
C. Labor relations
    1. Local
        a. Organized shops
        b. Open shops
    2. National organizations

Teaching Suggestions

Secure guest speakers from some of the largest (and most prominent) organizations—speakers who can make informative talks to the students—some for an organized shop and some for an open shop.

Instruct the student as to what he can expect from his profession; teach him how to make an application for employment and present it.

Student Assignments

Have each student fill in an application blank to present to you as though he was applying for a job; then interview each as though you were a prospective employer.

References

Crosby. *Person-to-Person Management.*
Haimann. *Professional Management.*
Hegarty. *How To Build Job Enthusiasm.*

Unit XXVI

SHOP ECONOMICS AND WORK RELATIONSHIPS

Training Time

Classroom, 3 hours

Objectives

To introduce the student to the fundamentals of economics pertaining to shops in which he will be employed. To acquaint him with the systems and procedures normally used to account for the various control functions.

To acquaint the student with the basic payroll principles so that he can understand deductions and make sensible decisions concerning benefits many companies make available to their employees through income deductions.

To encourage the student to improve his relationships with coworkers, when representing his employer to the customer, and when meeting the public.

Unit Outline

A. Shop economics
    1. Internal control systems
        a. Stock control
        b. Spare parts control
            (1) Within the shop
            (2) Quick pickup local
        c. Supply items
            (1) Cleaning agents
            (2) Wiping rags
        d. Vouchers
    2. Job assignments
        a. Time cards
        b. Wages
        c. Commission work
        d. Wages plus commission
        e. Salary
    3. Normal income deductions
        a. Federal income tax
        b. Form W–4, Employee's Withholding Exemption Certificate
        c. F.I.C.A. or F.O.A.B.
        d. State taxes, if any
        e. City taxes, if any
        f. Life, health, hospital, or accident insurance
        g. Savings bonds

h. Supplementary retirement annuities or pensions
i. Charitable organizations

B. Work relationships
1. Within the shop
a. Customer contact
b. Seniority status
c. Customer's property
d. Employer's property
2. Outside the shop
a. Representing employer
b. Public contact
(1) Wearing marked uniform
(2) Operating marked vehicle
c. Operating customer's equipment
d. Hauling customer's equipment

Teaching Suggestions

Reproduce sample forms relating to the various topics, as each is discussed, to hand out to the student. Help the student to understand as much about the typical shop control systems as possible. (Much of this can be practiced as he is receiving his training.)

Invite a guest speaker who is an income tax accountant, or one from a payroll office, or one who has a working knowledge of payrolls and deductions applicable to heavy construction equipment service shop operation.

Encourage the student to take pride in his work, to respect his employer, to respect the customer, and to discipline himself toward creating the maximum favorable impression in this environment.

Student Assignments

Have each student fill in the sample form handouts. Check them for accuracy and discuss student errors.

Have each student figure a hypothetical time loss problem resulting from an accident. (Hospitalization insurance agents can provide case figures.)

Reference

Niswonger and Fess. *Accounting Principles*, chapter 16, pp. 346–370.

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International Harvester, Construction Equipment Division. *Basic Hydraulics TE–6*. 10400 West North Avenue, Melrose Park, Ill. 60610.

International Harvester, Construction Equipment Division. *Power Shift Transmission CF–26*. 10400 West North Avenue, Melrose Park, Ill. 60610. (Current edition.)

International Harvester, Construction Equipment Division. *Torque Convertors CT–25*. 10400 West North Avenue, Melrose Park, Ill. 60610.

Snap-On Tools Corporation. *How's Your "Safety Rating"*. 5605 Bellarie Boulevard, Houston, Tex. 77036.

Texaco Library of Technical Aids. *Compressor Lubrication*. 135 East 42nd Street, New York, N.Y. 10017. (Current edition.)

Texaco Library of Technical Aids. *Operation and Care of Hydraulic Machinery*. 135 East 42nd Street, New York, N.Y. 10017. (Current edition.)

Films

Basic Shop Safety. Filmstrip, 87 frames, black and white. Jam Handy Organization, 2821 East Grand Boulevard, Detroit, Mich. 48211.

Summary: This series presents a complete safety program for wood and metal shops. Prevention of accidents and correct handling of equipment are stressed.

Electrical Circuits. Filmstrip, 57 frames. Society for Visual Education, Inc., 1345 Diversey Parkway, Chicago, Ill.

Summary: Describes circuits in general—the series, parallel, and compound circuits; Ohm's Law of Resistance. Defines terms.

Electrical Magnets. Filmstrip, 47 frames, black and white. Society for Visual Education, Inc., 1345 Diversey Parkway, Chicago, Ill.

Summary: How they differ from permanent magnets, size, shape, changing poles, flow of current. Shows uses in both household objects and industry. Gives details on how to make an electric magnet. Changing poles, current flow.

Permanent Magnets. Filmstrip, 47 frames, black and white. Society for Visual Education, Inc., 1345 Diversey Parkway, Chicago, Ill.

Summary: Depicts the size, shape, and comparative strength of permanent magnets. Shows what they attract and how they can be useful in many practical ways. Tells about the properties of North and South poles, compasses, and the earth.

Principles of Electrical Motors and Generators. Filmstrip, 68 frames, color. Society for Visual Education, Inc., 1345 Diversey Parkway, Chicago, Ill.

Summary: Discusses laws of electromagnetism. AC and DC motors and generators. Includes questions.

Principles of Fluids. Filmstrip, 49 frames, color. Society for Visual Education, Inc., 1345 Diversey Parkway, Chicago, Ill.

Summary: Explains Archimedes' principle of bouyant force, Pascal's principle of pressure, Bernoulli's principle of moving fluids.

Roll of Drums. 16 mm., 23 minutes, color. Caterpillar Dealer. (Local distributor.)

Summary: Shows the importance of brakes and demonstrates some casualties resulting from carelessness in neglecting to check brake systems.

Senior Safety Series. Filmstrip, 41 frames, color. McGraw-Hill Filmstrips, 330 West 42d Street, New York, N.Y.

Summary: Stresses that safety is an attitude rather than a mere set of rules. Includes suggestions for making the environment safer. Good safety practices are stressed.

Use of Machines in Our Industrial Life Series. Filmstrip, 52 frames, color. McGraw-Hill Filmstrips, 330 West 42d Street, New York, N.Y.

Summary: Shows how industrial tools developed and gives step-by-step directions for performing basic operations. Safety is stressed.

The Work of Gears. Filmstrip, 40 frames, 10 minutes, color. Society for Visual Education, Inc., 1345 Diversey Parkway, Chicago, Ill.

Summary: How gears, belts, and chains transfer power of engines and motors; how gears change direction of motion; mechanical advantage; use of different sized gears.

The Work of the Lever. Filmstrip, 41 frames, 10 minutes, color. Society for Visual Education, Inc., 1345 Diversey Parkway, Chicago, Ill.

Summary: First, second, third class levers; how to determine mechanical advantage. How to measure work done.

The Work of the Pulley. Filmstrip, 49 frames, 11 minutes, color. Society for Visual Education, Inc., 1345 Diversey Parkway, Chicago, Ill.

Summary: Operation of fixed and movable pulleys; mechanical advantages; measurement in foot-pounds; how pulleys are used.

Glossary

ABRASION: Wear by rubbing of coarse, hard, or sharp materials.

AFTER COOLER: Any device which will cool compressed air after it is fully compressed.

A-FRAME: An open structure tapering from a wide base to a load-bearing top.

AIR RECEIVER: The air storage tank on a compressor.

ALLOY STEEL: Steel compounded with other metals to improve its quality.

AMPERE: The intensity of electric current produced by one volt acting through a resistance of one ohm.

A.P.I.: American Petroleum Institute.

APRON: The front gate of a scraper body.

ATMOSPHERIC PRESSURE: Pressure of air enveloping the earth, averaged as 14.7 pounds per square inch at sea level, or 29.92 inches of mercury as measured by a standard barometer.

AUXILIARY: A helper or standby engine or unit.

AXIS: A straight line around which a shaft or body revolves.

AXLE, DEAD: A fixed shaft functioning as a hinge pin.

AXLE, LIVE: A revolving horizontal shaft.

BABBITT: A soft antifriction metal composed of tin, antimony, and copper in varying proportions.

BACK HAUL: A line which pulls a drag scraper bucket backward from the dump point to the digging point.

BACKHOE: A hoe or pull shovel.

BALLAST: Heavy material, such as water, sand, or iron, which has no function in a machine except to increase the weight.

BALL JOINT: A connection, consisting of a ball and socket, which will allow a limited hinge movement in any direction.

BEARING: A part in which a shaft or pivot revolves.

BEARING, ANTIFRICTION: A bearing consisting of an inner and outer ring, separated by balls or rollers held in position by a cage.

BEARING, NEEDLE: An antifriction bearing using very small diameter rollers between wide faces.

BEARING, PILOT: A small bearing that keeps the end of a shaft in line.

BEARING, SOLID: A one-piece bushing.

BEARING, THROWOUT: A bearing that permits a clutch throwout collar to slide along the clutch shaft without rotating with it.

BED: A base for machinery.

BELL CRANK: A lever whose two arms form an angle at the fulcrum, or a triangular plate hinged at one corner.

BITUMINOUS: Containing asphalt or tar.

BLEED: To remove unwanted air or fluid from passages.

BLOCK: A pulley and its case.

BLOCK, CROWN: A sheave set suspended at the top of a derrick.

BLOCK, SLING: A frame containing two sheaves mounted on parallel axles, so that they will line up when pulled from opposite directions.

BLOCK, SNATCH: A sheave in a case having a pull hook or ring.

BLOCK, TRAVELING: A frame for a sheave or a set of sheaves that slides in a track.

BOOM: In a revolving shovel, a beam hinged to the deck front, supported by cables.

BOOM, CRANE: A long, light boom, usually of lattice construction.

BOOM, JACK: A boom whose function is to support sheaves that carry lines to a working boom.

BOOM, LIVE: A shovel boom which can be lifted and lowered without interrupting the digging cycle.

BOOSTER: An auxiliary device that increases force or pressure.

BOOSTER PUMP: A pump that operates in the discharge line of another pump, either to increase pressure, or to restore pressure lost by friction in the line or by lift.

BOWL: The bucket or body of a carrying scraper.

BRAKE: A device for slowing, stopping, and holding an object.

BRAKE, DISC: A brake which utilizes friction between fixed and rotating discs, or between discs and shoes.

BRAKE DRUM: A rotating cylinder with a machined inner or outer surface upon which a brake band or shoe presses.

BRAKE, FRICTION: A brake operating by friction between two surfaces rotating or sliding on each other.

BRAKE HORSEPOWER: The horsepower output of an engine or mechanical device. Measured at the flywheel or belt, usually by some form of mechanical brake.

BRAKE, SELF-ENERGIZING: A brake that is applied partly by friction between its lining and the drum.

BRAZE: To solder with brass or other hard alloys.

BRIDLE CABLE: An anchor cable that is at right angles to the line of pull.

BRIDLE HITCH: A connection between a bridle cable and a cable or sheave block.

BRINNEL TEST: A method of determining the hardness of metal by the indentation of a standard steel ball of known hardness under a definite load.

BUCKET LOADER: Usually a chain bucket loader, sometimes a tractor loader or shovel dozer.

BUCKET SHEAVE (PADLOCK SHEAVE): A pulley attached to a shovel bucket, through which the hoist or drag cable is reeved.

BUCKET, SLAT: An openwork bucket made of bars instead of plates, used in digging sticky soil.

BULL CLAM: A bulldozer fitted with a curved bowl hinged to the top of the front of the blade.

BULL GEAR: A toothed driving wheel which is the largest or strongest in the mechanism.

BULL WHEEL: A large driving wheel or sprocket.

BULLDOZER: A tractor equipped with a front pusher blade.

BULLGRADER: Trade name for an International (formerly Bucyrus-Erie) angling dozer.

BUMPER (GUARD): A slotted or perforated plate that holds a check-type air valve near its seat.

BURN: To cut with a torch.

BUSHING: A metal cylinder between a shaft and a support, or a wheel, that serves to reduce rotating friction and to protect the parts.

BUSHING, SPLIT: A bushing made in two pieces, for ease of insertion and removal.

BUTT JOINT (OPEN JOINT): In pipe, flat ends that meet but do not overlap.

CABLE: Rope made of steel wire.

CABLE, BACKHAUL: In a cable excavator, the line that pulls the bucket from the dumping point back to the digging point.

CABLE CONTROL UNIT: A high-speed tractor winch having one to three drums under separate control. Used to operate dozers and towed equipment.

CABLE, DRAG: In a dragline or hoe, the line that pulls the bucket toward the shovel.

CABLE EXCAVATOR: A long-range, cable-operated machine which works between a head mast and an anchor.

CABLE, INHAUL (DIGGING LINE): In a cable excavator, the line that pulls the bucket to dig and bring in soil.

CAGE: A circular frame that limits the motion of balls on rollers in a bearing.

CAM: A rotating or sliding piece, or a projection on a wheel, used to impart exactly timed motion to light parts.

CAMBER: Vertical convex curve in a culvert barrel.

CANTILEVER: A lever-type beam that is held down at one end, supported near the middle, and supports a load on the other end.

CAPSTAN (CAT HEAD): A nonwinding winch used with soft rope.

CARBIDE: Tungsten carbide, a very hard and abrasion-resistant compound used in drill bits and other tools.

CARBON STEEL: Usually a hardened steel not alloyed with other metals.

CARRIAGE: A sliding or rolling base or supporting frame.

CARRIER: A rotating or sliding mounting or case.

CAT: A trade marked designation for any machine made by the Caterpillar Tractor Co. Widely used to indicate a crawler tractor or mounting of any make.

CAT HEAD: A capstan winch.

CATSKINNER: Operator of a crawler tractor.

CENTER OF GRAVITY: That point in a body about which all the weights of all the various parts balance. It is found experimentally by balancing on a knife edge or a point.

CENTERPIN (CENTER PINTLE): In a revolving shovel, a fixed vertical shaft around which the shovel deck turns.

CENTIGRADE: A temperature scale on which the freezing point of water at sea level atmospheric pressure is indicated as 0° and its boiling point as 100°. Degrees centigrade (°C) equals Fahrenheit (°F) minus 32 multiplied by ⅝.

CENTRIFUGAL FORCE: Outward force exerted by a body moving in a curved line. It is the force which tends to tip a car over in going around a curve.

CETANE NUMBER: An indication of diesel fuel ignition quality. The cetane number of a fuel is the percentage by volume of cetane in a mixture of cetane and alpha-methylnapthlalene which matches the unknown fuel in ignition quality.

American diesel oil usually varies from 30 to 60 cetane.

CHAIN, SILENT: A roller-type chain in which the sprockets are engaged by projections on the link side bars.

CHANFER (CHAMFER): To bevel or slope an edge or corner.

CHECK VALVE: Any device which will allow fluid or air to pass through it in only one direction.

CHOCK: A block used under and against an object to prevent it from rolling or sliding.

CHOKER: A chain or cable so fastened that it tightens on its load as it is pulled.

CIRCLE: In a grader, the rotary table which supports the blade and regulates its angle.

CLAM: A clamshell bucket.

CLOSING LINE (DIGGING LINE): The cable which closes the jaws of a clamshell bucket.

CLUTCH: A device which connects and disconnects two shafts which revolve in line with each other.

CLUTCH, AUTOMATIC: A clutch whose engagement is controlled by centrifugal force, vacuum, or other power without attention by the operator.

CLUTCH BRAKE: A device to slow the jackshaft when a clutch is released, to permit more rapid gear shifting.

CLUTCH, CENTRIFUGAL: A clutch that is kept in engagement only by centrifugal force, so that it automatically disconnects the power train when the engine idles.

CLUTCH, DISC: A coupling that can be engaged to transmit power through one or more discs squeezed between a back plate and a movable pressure plate, and that can be disengaged by moving the plates apart.

CLUTCH, FLUID: A fluid coupling other than a torque converter.

CLUTCH, LOCKUP: A clutch that can be engaged to provide a nonslip mechanical drive through a fluid coupling.

CLUTCH, OVERRUNING (FREE WHEELING UNIT): A coupling that transmits rotation in only one direction and disconnects when the torque is reversed.

CLUTCH, SLIP (SAFETY CLUTCH): A friction clutch that protects a mechanism by slipping under excessive load.

CLUTCH, WET (OIL CLUTCH): A clutch that operates in an oil bath.

COCKPIT: The part of a tractor or grader containing the operator's seat and controls.

COLLAR: A sliding ring mounted on a shaft so that it does not revolve with it. Used in clutches and transmissions.

COMPENSATING DRIVE: In a four-wheel drive truck, a free wheeling unit in the front propeller shaft that allows the front wheels to go farther than the rear on curves.

COMPRESSION RATIO: The ratio of the volume of space above a piston at the bottom of its stroke to the volume above the piston at the top of its stroke.

COMPRESSOR: A machine which compresses air.

CORROSION: Wear or dissolving away through chemical action as by rusting, or acids.

COUNTERSHAFT: A shaft which receives power from a parallel mainshaft, and transmits it to another part of the mainshaft or to working parts.

COUNTERWEIGHT: A "dead" or nonworking load attached to one end or side of a machine to balance weight carried on the opposite end.

CRADLE: A support bracket with a hinged connection to its load.

CRANE: A mobile machine used for lifting and moving loads without use of a bucket.

CRANKSHAFT: The engine shaft that converts the reciprocating motion and force of pistons and connecting rods to rotary motion and torque.

CRAWLER: One of a pair of roller chain tracks used to support and propel a machine, or any machine mounted on such tracks.

CROWD: The process of forcing a bucket into the digging, or the mechanism which does the forcing. Used chiefly in reference to machines which dig by pushing away from themselves.

CYLINDER, SLAVE: A small cylinder whose piston is moved by a piston rod controlled by a larger cylinder.

DENSITY: The ratio of the weight of a substance to its volume.

DETAIL DRAWING: A large scale drawing showing all small parts, details, dimensions, etc.

DIAPHRAGM: A flexible partition between two chambers.

DIESELING: In a compressor, explosions of mixtures of air and lubricating oil in the compression chambers or other parts of the air system.

DIFFERENTIAL: A device that drives two axles and allows them to turn at different speeds to adjust to varying resistance.

DIFFERENTIAL, NONSPIN (LIMITED ACTION DIFFERENTIAL): A differential that will turn both axles, even if one offers no resistance.

DIGGING LINE: On a shovel, the cable which forces the bucket into the soil. Called crowd in a dipper shovel, drag in a pull shovel, and dragline and closing line in a clamshell.

DIPPER: A digging bucket rigidly attached to a stick or arm.

DIPPER STICK: A name for the standard revolving shovel (dipper shovel), and for the straight shaft which connects the bucket with the boom.

DOG: A heavy duty latch.

DONKEY: A winch with two drums which are controlled separately by clutches and brakes.

DOUBLE-CLUTCHING: Disengaging and engaging the clutch twice during a single gear shift, in order to synchronize gear speeds.

DRAG: Pulling a bucket into the digging, or the mechanism by which the pulling is done or controlled.

DRAGLINE: A revolving shovel which carries a bucket attached only by cables, and digs by pulling the bucket toward itself.

DRAGSHOVEL (HOE, BACKHOE, OR PULLSHOVEL): A shovel equipped with a jack boom, a live boom, a hinged stick, and a rigidly attached bucket, that digs by pulling toward itself.

DRAWBAR: In a tractor, a fixed or hinged bar extending to the rear, used as a fastening for lines and towed machines or loads.

DRUM: A rotating cylinder with side flanges, used for winding in and releasing cable.

DYNAMIC: Forces tending to produce motion.

DYNAMIC BALANCE: A condition of rest created by equal strength of forces tending to move in opposite directions.

ECCENTRIC: A wheel or cam with an off-center axis of revolution.

FAIRLEAD: A device which lines up cable so that it will wind smoothly onto a drum.

FERRULE: A short unthreaded tube or bushing, shrunk or soldered onto a tube or line.

FITTING, WEDGE SOCKET: A wire rope attachment in which the rope lies in a too-small groove between a wedge and a housing, so that pull on the rope tightens the wedge.

FLUID CLUTCH: A hydraulic coupling which does not increase torque.

FLUID DRIVE: A connection between two shafts that transmits torque through a fluid.

FOOT-POUND: Unit of work equal to the force in pounds multiplied by the distance in feet through which it acts. When a one-pound force is exerted through a one-foot distance, one foot-pound of work is done.

FORK: A two-pronged rod or yoke used to slide shifting collars along their shafts.

FRONT END LOADER: A tractor loader with a bucket which operates entirely at the front end of the tractor.

FULCRUM: A pivot for a lever.

GANTRY: An overhead structure that supports machines or operating parts.

GEAR, BULL: A gear or sprocket that is much larger than the others in the same power train.

GEAR, CLUSTER: Two or more gears of different sizes made in one solid piece.

GEAR, HELICAL: A gear with straight or curved teeth cut at an angle of less than 90° to the direction of rotation.

GEAR, HERRINGBONE: A gear with V-teeth.

GEAR, IDLER: A gear meshed with two other gears that does not transmit power to its shaft. Used to reverse direction of rotation in a transmission.

GEAR, PINION: A drive gear that is smaller than the gear it turns.

GEAR, PLANETARY SET: A gear set consisting of an inner (sun) gear, an outer ring with internal teeth, and two or more small (planet) gears meshed with both the sun and the ring.

GEAR, SPROCKET: A gear that meshes with roller or silent chain.

GENERAL DRAWING: A drawing showing elevation plan and cross section of the structure, also the borings for substructure and the main dimensions, etc.

GRAPPLE: A clamshell-type bucket having three or more jaws.

GYPSY SPOOL (CAT HEAD): A capstan winch.

HOE (BACKHOE, PULLSHOVEL): A shovel that digs by pulling a boom-and-stick-mounted bucket toward itself.

HOLDING LINE: The hoist cable for a clamshell bucket.

HOOK, SAFETY (LOCKON HOOK): A round hook with a hinged piece across the opening, that allows a line to enter it readily, but requires special manipulation to remove it.

HOOK, SWIVEL: A hook with a swivel connection to its base or eye.

HORSEPOWER: A measurement of power that includes the factors of force and speed.

HYDROMETER: Relating to pressure or equilibrium of fluids.

HYPOID: A pinion-and-ring gear set transmitting rotation through a right angle by means of teeth

having structure intermediate between a bevel and a worm set.

IMPELLER: A rotary pump member using centrifugal force to discharge a fluid into outlet passages.

INERTIA: The property of matter by which it will remain at rest, or in uniform motion in a straight line, unless acted upon by an external force.

INHAUL: The line or mechanism by which a cable excavator bucket is pulled toward the dump point.

INTERCOOLER: A radiator in which air is cooled while moving from low-pressure to high-pressure cylinders of a two-stage compressor.

JACK BOOM: A boom which supports sheaves between the hoist drum and the main boom in a pull shovel or a dredge.

JACKLEG: An outrigger post.

JACKSHAFT: A short drive shaft, usually connecting a clutch and transmission.

JIB BOOM: An extension piece hinged to the upper end of a crane boom.

JOURNAL: That part of a rotating shaft or axle which turns in a load-supporting bearing.

LAGGING: The surface or contact area of a drum or flat pulley, especially a detachable surface or one of special composition.

LEVER: A bar that pivots so that force applied at one part can do work at another, usually with a change in the force–distance ratio.

LIP: The cutting edge of a bucket. Applied chiefly to edges including tooth sockets.

LOAD FACTOR: Average load carried by an engine, machine, or plant, expressed as a percentage of its maximum capacity.

MANIFOLD: A chamber or tube having a number of inlets and one outlet, or one inlet and several outlets.

OCTANE NUMBER: Percent of iso-octane by volume in a mixture of iso-octane and normal heptane that has the same antiknock character in a standard variable compression Cooperative Fuel Research test engine as the fuel under test. Octane has antiknock characteristics. A mixture having 75 percent octane and 25 percent heptane is said to have an octane rating of 75.

OHM: Unit of electrical resistance to current flow. It is equal to a fall in potential of one volt when a current of one ampere flows.

OSCILLATION: Independent movement through a limited range, usually on a hinge.

OUTRIGGER: An outward extension of a frame which is supported by a jack or block. Used to increase stability.

PAD (SHOE OR PLATE): Ground contact part of a crawler-type track.

PILOT VALVE: In a compressor, an automatic valve which regulates air pressure.

PISTON DISPLACEMENT: The amount of air displaced by moving all pistons of an engine or compressor from the bottom to the top of their stroke.

PISTON, SLAVE: A small piston having a fixed connection with a larger one.

PNEUMATIC: Powered or inflated by compressed air.

POPPET VALVE: A valve shaped like a mushroom, resting on a circular seat, and opened by raising the stem. Standard automotive equipment.

POWER TRAIN: All moving parts connecting an engine with the point or points where work is accomplished.

PRESSURE PLATE: In a clutch, a plate driven by the flywheel or rotating housing, which can be slid toward the flywheel to engage the lined disc or discs between them.

PROPEL SHAFT: In a revolving shovel, a shaft which transmits engine power to the walking mechanism.

P.S.I. (psi): Pressure in pounds per square inch.

PULLEY: A wheel that carries a cable or belt on part of its surface.

PULL SHOVEL (DRAGSHOVEL OR HOE): A shovel with a hinge-and-stick-mounted bucket that digs while being pulled inward.

PUMP, CENTRIFUGAL: A pump that moves water by centrifugal force developed by rapid rotation of an impeller.

PUSHER: A tractor that pushes a scraper to help it pick up a load.

RACES: The inner and outer rings of a ball or roller bearing.

RADIAL: Lines converging at a single center.

RAM: A hydraulic cylinder.

RECEIVER: The air tank or reservoir on a compressor.

REDUCTION, DOUBLE: Two sets of gears in series that both reduce speed and increase power.

REEVING: Threading or placement of a working line.

REFUSAL: The depth beyond which a pile cannot be driven.

RELIEF VALVE: A valve which will allow air or fluid to escape if its pressure becomes higher than the valve setting.

RETRACT: The mechanism by which a dipper shovel bucket is pulled back out of the digging.

REVERSING CLUTCH: A forward-and-reverse transmission which is shifted by a pair of friction clutches.

RHEOSTAT: A device that regulates flow of electricity by varying the amount of resistance in the circuit.

ROLLER, HOOK: In a revolving shovel, a roller attached by a bracket to the revolving section, and contacting the lower face of a circular tract on the travel unit.

ROTOR: Any unit that does its work in a machine by spinning, and does not drive other parts mechanically.

SAFETY CLUTCH: A clutch that slips instead of transmitting loads beyond the capacity of the machine.

SCHEMATIC: Showing principles of construction of operation, without accurate mechanical representation.

SCRAPER (CARRYING SCRAPER) (PAN): A digging, hauling, and grading machine having a cutting edge, a carrying bowl, a movable front wall (apron), and a dumping or ejecting mechanism.

SCRAPER, BOTTOM DUMP: A carrying scraper that dumps or ejects its load over the cutting edge.

SCRAPER, REAR DUMP: A two-wheel scraper that dumps at the rear.

SHEAVE (pronounced "shiv"): A grooved wheel used to support cable or change its direction of travel.

SHEAVE, PADLOCK: The bucket sheave on a dipper or hoe shovel.

SHEAVE, TRAVELING: A sheave block that slides in a track.

SHOVEL, DIPPER (DIPPER STICK): A revolving shovel that has a push-type bucket rigidly fastened to a stick that slides on a pivot in the boom.

SLACK ADJUSTER: In air brakes, the connection between the brake chamber and the brake cam.

SLAVE UNIT: A machine which is controlled by or through another unit of the same type.

SLING: A lifting hold consisting of two or more strands of chain or cable.

SNATCH BLOCK: A pulley in a case which can be easily fastened to lines or objects by means of a hook, ring, or shackle.

SPECIFIC GRAVITY (SOLIDS OR LIQUIDS): The ratio of the mass of a body to an equal volume of water.

SPIDER GEAR (CARRIER PINION): A differential gear which rotates on its shaft in a rotating case.

SPRING LOADED: Held in contact or engagement by springs.

SPROCKET: A gear that meshes with a chain or a crawler track.

STATOR (REACTOR): In a torque converter, a set of fixed vanes that change the direction of flow of fluid entering the pump or the next stage turbine.

STEERING BRAKE: A brake which slows or stops one side of a tractor.

STEERING CLUTCH: A clutch which can disconnect power from one side of a tractor.

SUCTION: Atmospheric pressure pushing against a partial vacuum.

SUN GEAR: The central gear in a planetary set.

SUPERCHARGER: A blower that increases the intake pressure of an engine.

SYNCHROMESH: A silent-shift transmission construction, in which hub speeds are synchronized before engagement by contact of leather cones.

TAGLINE: A line from a crane boom to a clamshell bucket that holds the bucket from spinning out of position.

TANDEM: A double-axle drive unit for a truck or grader.

TANGENT: A line that touches a circle and is perpendicular to its radius at the point of contact.

THROW: The longest straight distance moved in the stroke or circle of a reciprocating or rotary part.

THROWOUT BEARING: A bearing, sliding on a clutch jackshaft, that carries the engage-and-disengage mechanism.

TORQUE CONVERTER: A hydraulic coupling which utilizes slippage to multiply torque.

TRANSMISSION: A gear set that permits change in speed-power ratio and/or direction of rotation.

TRANSMISSION, COMPOUND: A gear set in which power can be transmitted through two sets of reduction gears in succession.

TURBINE: A rotary engine driven by pressure of liquid or gas against its vanes.

UNIVERSAL JOINT: A connection between two shafts that allows them to turn or swivel at an angle.

VENTURI: A pressure jet that draws in and mixes air.

VISCOSITY: The resistance of a fluid to flow. A liquid with a high viscosity rating will resist flow more readily than will a liquid with a low viscosity.

VOLT: The electromotive force which will cause a current of one ampere to flow through a resistance of one ohm.

WATT: The power of a current of one ampere flowing across a potential difference of one volt.

WHEEL, BULL: A driving sprocket for a crawler track.

WINCH: A drum that can be rotated so as to exert a strong pull while winding in a line.

WINCH, CAPSTAN (CATHEAD): A revolving spool that exerts a pull by friction with one or more loops of fiber rope.

WORKING CYCLE: A complete set of operations.

WORKING DRAWING: Any drawing showing sufficient detail so that whatever is shown can be built without other drawings or instructions.

WORM: A gear formed of a cylinder with spiral threads cut in its surface.

WORM WHEEL: A modified spur gear with curved teeth that meshes with a worm.

Appendixes

Appendix A

SUGGESTED TRAINING FACILITY

The suggested floor plan on the following page is for a minimum size class of 20 students and one instructor. All facilities are within the same structure to provide better control of students for a more effective learning situation.

Interior partitions should have ample windows to enable the instructor to have a view of the entire shop from almost any position. The dressing area and restrooms should be the only areas completely partitioned for privacy.

Tool rooms should have a permanent wall structure about 4 feet high, enclosed from that height to the ceiling with wire mesh. Air compressors should be placed in a shed adjacent to the shop, away from the classroom area, to provide an explosion-free air supply and to keep the noise level down.

The suggested minimum tool, equipment, and training aid list provides shop training material only. Normally, students should buy their own starter set of tools while in training so that they will have them when they begin their careers as mechanics.

Classrooms adjacent to, or part of, the shop are beneficial to teaching efficiency, for many times the instructor needs to assemble his class for special instruction and the time lost between class and shop is reduced to a minimum.

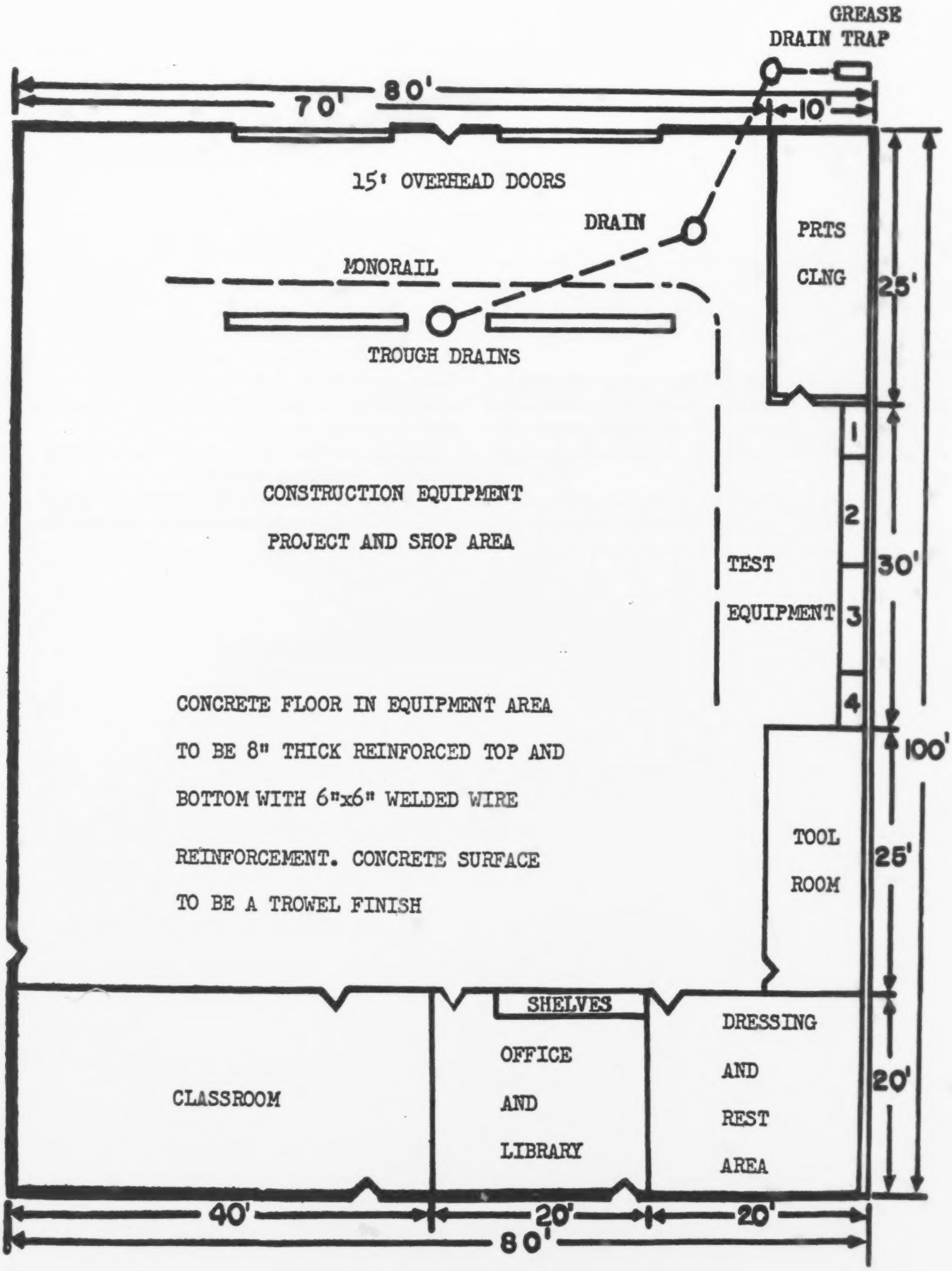

Figure 8. Suggested training facility.

Appendix B

SUGGESTED EQUIPMENT, TOOLS, AND TRAINING AIDS*

A. Equipment	Cost
1. Test equipment	
a. Fuel pump tester	$422.35
b. Injector nozzle tester	5,341.00
c. Spring tester	35.00
d. Diesel compression tester	120.00
e. Steam cleaner	800.00
f. Hydraulic system tester	425.00
Total	7,143.35
2. Hoisting	
a. Mobile floor crane 5000#	880.00
b. Overhead traveling hoist, track or A frame	780.00
c. Two pull lift chain hoists	780.00
Total	2,440.00
3. Presses, pullers, jacks, and stands	
a. Hydraulic roll bed press and attachments	3,500.00
b. Hydraulic ram puller-installer and attachments for gears and bushings	640.00
c. Hydraulic sleeve puller-installer and attachments	195.00
d. Hydraulic jacks (5)	750.00
e. Jack stands	150.00
f. Mobile hydraulic transmission jack and attachments	225.00
g. Creepers, rollers (6)	60.00
h. Engine position stands (2 each)	1,080.00
Total	6,600.00
4. Oxyacetylene burning and welding	300.00
5. Heavy duty electric arc welder, helmet, etc	1,450.00
6. Battery charger, heavy duty	$220.00
7. Bench or pedestal grinder-buffer	157.50
8. Parts cleaning equipment	225.00
9. Armature growler	45.00
10. Engine analyzer	950.00
11. Drill press	395.00
12. Alternator set universal	385.00
13. Alemite lubrication equipment, hoses and fittings	135.00
14. Electric etching tool marker	22.50
15. Spark plug cleaner	85.00
16. Valve shop	1,200.00
17. Work benches	740.00
18. Tool cabinets and chest	850.00
19. Batteries (2)	260.00
Total	7,420.00
Total, equipment	23,603.35

B. Tools	
1. Precision instruments	
a. Micrometers	325.00
b. Dial indicators	48.00
c. Timing gauges	24.50
d. Feeler gauges (3)	6.00
e. Gap gauges, spark plug	2.50
Total	406.00
2. Electrical tools	
a. Drill, motor, portable, ¼''; and drill, motor, portable, ½''	140.00
b. Impact motors, 1 each, ½'', ⅝'', 1'' drives	600.00
c. Portable grinder-sander	211.50
d. Soldering guns and irons	75.00
Total	1,026.50

*Prices estimated in 1967.

3. Wrench sets and drives	
a. 1'' drive socket sets	$453.00
b. ¾'' drive socket sets	170.00
c. ½'' drive socket sets	62.50
d. ¼'' drive socket sets	35.00
e. Combination wrench sets, 1/32'' graduations (3)	192.00
f. Open-end wrench sets (3)	150.00
g. Flare-nut wrench sets	34.60
h. Allen wrench sets	18.50
i. Ignition wrench set	10.30
j. Torque wrench and torque multipliers	450.00
Total	1,575.90
4. Special tools	
a. Tap and die sets, NC & NF	185.00
b. Bushing driver sets	35.00
c. Punch sets	20.00
d. Tube cutting and flaring kits (2)	30.00
e. Injector tube replacer kit	150.00
f. Self-alining reamer set	120.00
g. Expanding reamer set	250.00
h. Tappet adjusting tools (2)	5.50
i. Universal clutch alining set	12.50
j. Spanner wrenches	65.00
k. Hones, cylinder (3)	48.00
l. Ring compressors and expanders (2)	17.50
Total	938.50
5. Adjustable wrenches	
a. Open-end	45.00
b. Pipe	45.00
c. Chain	35.00
Total	125.00
6. Pliers	
a. Slip joint	3.00
b. Channel lock	4.50
c. Needle nose, straight and offset	4.50
d. Retaining ring	4.50
e. Snap ring	3.95
f. Hose clamp	3.50
g. Lineman	4.25
h. Diagonal cutters	$3.80
i. Brake spring	6.00
Total	38.00
7. Bars	
a. Wrecking	18.00
b. Rolling head pry (2)	7.80
Total	25.80
8. Screwdrivers, all types	37.50
9. Hammers, mallets, and sledges	50.00
10. Chisels	26.00
11. Hacksaw frames and blades	60.00
12. Tinner's snips	16.80
13. Tube benders	110.00
14. Valve lifters, "C" clamp and stubby	19.00
15. Hand grease guns, lever action (2)	10.40
16. Battery carriers (2)	4.00
17. Heavy duty booster cables (2)	12.00
18. Blow guns adaptable to air hoses (5)	12.50
19. Hand oilers, trigger actuated (3)	9.00
20. Extension lights (10), conductors (3)	30.00
21. Flow control crankcase fillers (2)	18.90
22. Galvanized radiator filler	3.90
23. Hydrometer	7.50
Total	427.50
Total, tools	4,563.20
C. Training Aids	
1. 16-mm. sound motion picture projector and screen	750.00
2. Overhead projector	200.00
3. Strip film-slide projector, with synchronous sound	425.00
4. Chart stand and instructional charts	250.00
5. Students' textbook	8.80
6. Study guide	2.50
7. Reference library	1,500.00
8. Service manuals (normally, no cost)	
Total, training aids	3,136.30
Grand total	31,302.85

U.S. GOVERNMENT PRINTING OFFICE: 1969 O-351-946